IOWA

GEOLOGICAL SURVEY

VOLUME VII.

ANNUAL REPORT, 1896,

WITH

ACCOMPANYING PAPERS.

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In Areal Work.	
NELLIE E. NEWMAN	SECRETARY

GEOLOGICAL BOARD.

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FIFTH ANNUAL

Report of the State Geologist.

IOWA GEOLOGICAL SURVEY,
DES MOINES, December, 31, 1896.

To Governor F. M. Drake and Members of the Geological Board:

GENTLEMEN—I have the honor to report that during 1896 the work of the Iowa Geological survey has been carried forward in accordance with the plans approved by the board at the beginning of the year. In selecting the counties to be investigated the survey was influenced by two considerations. First, these counties contain geological deposits of great economic importance, and it seemed desirable to have them brought to public attention as early as convenient. Second, the counties were so chosen as to elucidate as large a number of geological problems as possible. With the solution of questions relating to the indurated rocks and the overlying loose or superficial deposits in certain carefully selected typical localities, the work in other localities may be prosecuted more expeditiously and more satisfactorily. With this end in view investigations were made in Johnson county for the purpose of extending the work begun by Professor Norton, on the Devonian system of Iowa, in Linn. The geological formations of Johnson county carry the Devonian section up through more than seventy feet of strata not represented in Linn county, though the lowest Devonian beds in the first named county are the exact equivalents of beds well described

IOWA GEOLOGICAL SURVEY

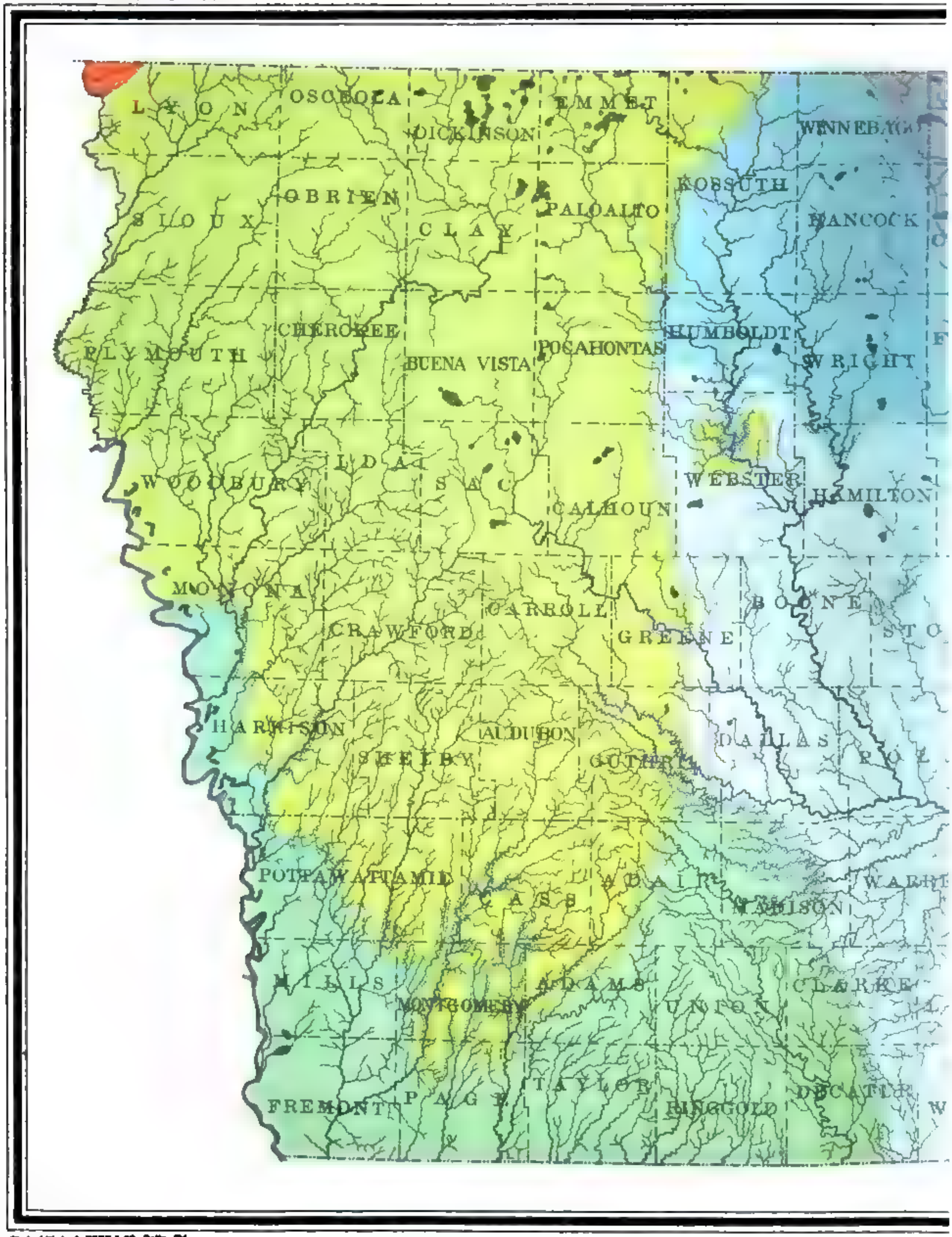


Photo-Lith. by A. HOEN & CO., Balto., Md.

county constitutes one of the most important of the areas surveyed during the past season. The work in Polk county was done by Mr. H. F. Bain. It was indeed begun some years ago, but it was carried on only in short intervals spared from pressing duties in the office. Owing to the importance of the area from both a stratigraphic and an economic point of view, it was deemed wise to press the work to completion during the field season of 1896. In connection with his work on Polk county Mr. Bain has also made a complete survey of Guthrie county. Guthrie county carries the Carboniferous section from the Des Moines stage with which the section ends in Polk, up through a portion of the Missouri stage; and in this county there is furthermore a marginal deposit of special interest belonging to the Upper Cretaceous. The problems in both Polk and Guthrie are very intricate, but they have been worked out with great success, as will be recognized by consulting the reports of Mr. Bain included in the present volume.

Madison county shows more clearly than either Polk or Guthrie, certain interesting phases developed in the southward extension of the Des Moines and Missouri stages of the Carboniferous. The Winterset limestone, the lowest member of the Missouri stage, is important, not only on account of its utility as a building stone, but because it marks a very definite stratigraphic horizon. It seemed desirable to make a careful study of this limestone, together with the beds immediately above and below it in order that the work in Iowa may be properly correlated with that done on the Upper Carboniferous strata by the geologists of Missouri and Kansas. Madison county was therefore selected for investigation, and was assigned to Professor Tilton, of Indianola. Professor Tilton received instructions to note carefully the successive changes in the conditions of sedimentation which the beds of the county record, and to take particular account of the faunal changes in passing from the beds below the Winterset horizon to those above it. The oil and gas horizons of

southeastern Kansas occur in Upper Carboniferous strata and the supply is related to certain well defined beds that may be traced through southwestern Iowa.

In the counties named the superficial deposits present problems of scarcely less interest than the indurated rocks. Johnson and Marshall are traversed by the extreme southern margin of the Iowan drift, and both counties contain heavy beds of loess that are genetically connected with the melting and retreat of the Iowan ice. Cerro Gordo county illustrates the character of the Iowan till at some distance back from its southern margin, while the western part of the county is occupied by morainic hills and ridges and characteristic kettle holes, which in this region mark the eastern margin of the Wisconsin drift. The western part of Marshall county also shows the influence of the Wisconsin drift sheet, and the extreme southern limit of the Wisconsin lobe is found at the south end of Capitol Hill in Des Moines, Polk county. In Polk county the Wisconsin drift overrides loess of Iowan age in the northern part of the city of Des Moines, while to the northwest this drift rests on till of Kansan age. The oldest drift sheet, so far recognized in Iowa, a drift older than the Kansan, is also exposed in Polk county. The southwestern margin of the Wisconsin drift passes through Guthrie county, making this county one of the strategic areas in which to study the superficial deposits.

From an economic standpoint the soils of Iowa constitute the most important geological formations in the state. The first step in the study of soils necessitates a careful investigation of the superficial deposits, and accurate mapping to show their distribution. The composition of soils in any given area, and the purpose to which they are best adapted, depend wholly on the character of the loose surface materials. Soils on drift covered areas vary with the age and origin of the drift itself. Loess soils have their special characteristics and uses. While in the matter of soils Iowa, as in many other respects, has the best, yet the highest rewards of

agriculture will not be realized until the husbandman takes advantage of information furnished by the geologist and, recognizing the fundamental differences in soils, adapts crops and methods of culture to the needs and possibilities of his particular area.

The study of the drift, and of the loose surface materials derived from it, has an economic bearing in another direction. Enormous quantities of vegetable matter have been included between successive sheets of till, and the decomposition of the organic materials thus included in the superficial deposits generates natural gas. In a few known areas this gas has been stored in sufficient amount to make it useful in the heating and lighting of dwellings, and the information at hand justifies the conclusion that the conditions necessary for the generation and storage of gas from this source are best fulfilled near the terminal margin of an overlapping sheet of drift.

The six counties named above, are geologically important therefore, in respect to both indurated rocks and superficial deposits, and reports on these counties accompanied by the necessary maps and drawings are herewith submitted in the confident belief that they will be found of great practical interest to the people of Iowa.

In addition to the counties reported on in the published volumes of the Survey, and the six counties described in this report, the field work is partly or wholly completed in Buchanan, Delaware, Fayette, Howard, Cedar, Scott, Dallas, Story, Plymouth, Union, Lyon and Marion.

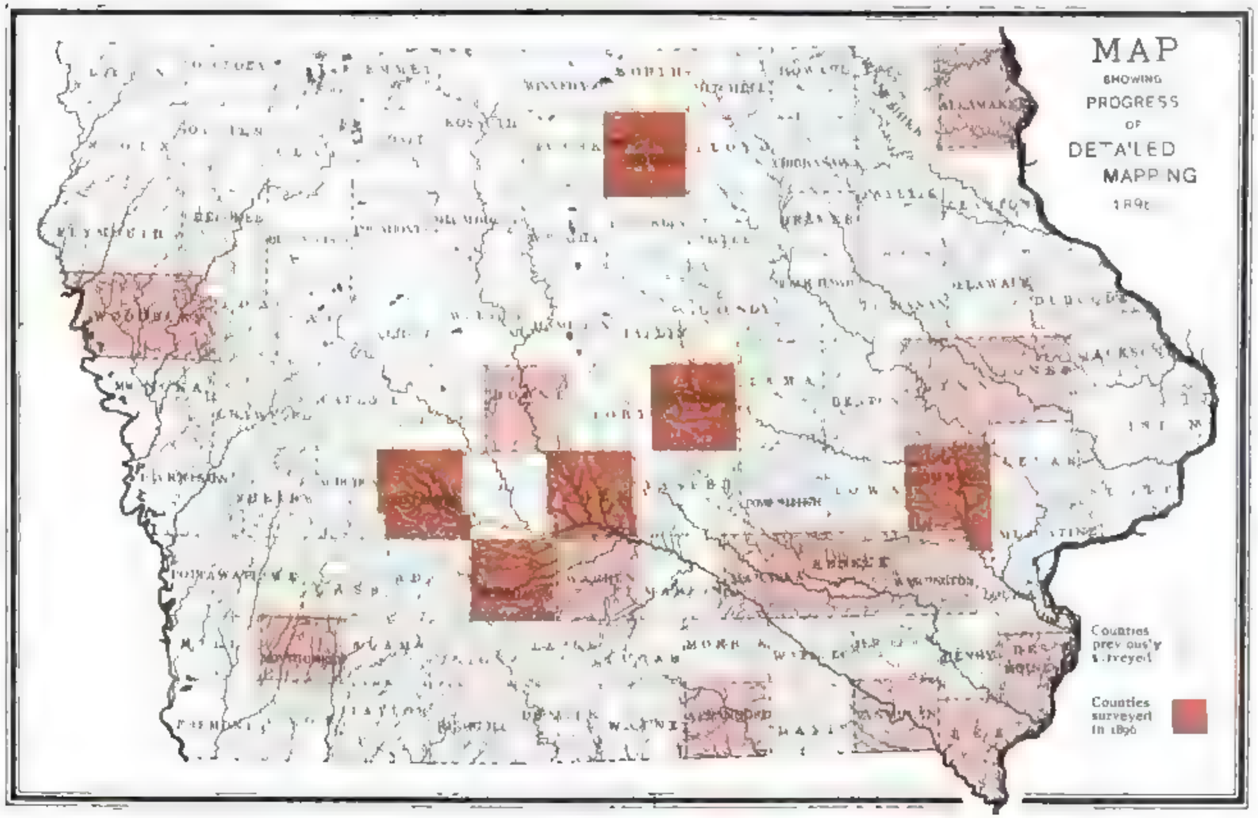
The year's work has also included the publication and distribution of Volume V, of the reports of the Survey, besides the monograph of Mr. A. G. Leonard on the lead and zinc of Iowa, and that of Dr. Beyer on the Sioux quartzite. These last two publications will constitute a part of Volume VI of the reports of the Iowa Geological Survey. The remainder of the volume will be occupied by the elaborate and valuable report of Professor Norton on the Artesian Wells of Iowa,

the manuscript of which, with necessary illustrations, is now ready for the printer.

We have also on hand, ready for publication, a paper by Professor Pammel on the Grasses of Iowa. Intelligent farmers will find this last paper of much practical interest. Its early publication is recommended.

It is gratifying to note that the publications of the Survey are being more and more appreciated, and are received by the people of the state, as well as by men of science everywhere, with increasing favor. Requests for copies of the reports from persons to whom they would be of great value, but who, under a strict construction of the present law governing the distribution of the volumes, are not entitled to receive them, are very numerous and indicate a widespread interest in the geological resources of the state. High schools in counties already reported on have introduced the separate county reports as works to be read by the pupils studying geology, and so have adopted one of the best possible methods for disseminating the information collected by the survey. Newspapers, with their usual public spirit, have aided in disseminating information by summarizing reports of local interest. Mr. Leonard's paper on lead and zinc was published entire, with illustrations, by some of the papers of Dubuque. Some modification of the law relating to distribution, whereby interested citizens of Iowa may obtain the reports without charge, is greatly to be desired.

Building Stones.—During the year the testing of the collection of building stones mentioned in the last annual report has been completed and the results are now being prepared for publication. The collection included specimens from many of the more important quarries of the state and from some undeveloped ledges. Unfortunately the collection was not as complete as could be desired, though an effort was made to obtain samples from all the principal quarries. Many of the quarrymen failed to respond at all, and others did not send in the required cubes at the specified time. The work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Counties previously surveyed
Counties surveyed in 1896

must accordingly be regarded as essentially preliminary, though it is complete as far as it was carried on. In all thirty-three specimens were tested, representing thirteen quarries in eight formations.

The specimens were dressed to two-inch cubes and then subjected to compression tests, the work being done at Ames by Prof. A. Marston and Messrs. Murray and Bain. Duplicate specimens were studied at Drake University, chemical analyses being made by Mr. Harry McCormick and absorption tests by Mr. H. B. Murray. The survey is under great obligations to these gentlemen and to Professor Marston for their co-operation. Mr. Bain is summarizing the results, which will be published in some of the future reports of the survey and will probably also be given local publication. The various quarry owners have already been informed by letter of the results of the tests on their stone.

Cement.—The past year has been an unfavorable one for the development of new industries in the state, so that no progress has been made in the direction of opening up the cement beds. The material shipped Mr. S. B. Newberry for examination was found to be too low in lime for use alone. It will be necessary to find in the neighborhood beds of purer chalk to mix with the other material. It is believed that this can be done, and Mr. Bain is to take up the work in Plymouth county for the coming season, with a view, among other things, of clearing up this matter.

Studies pursued with the object of determining the distribution of certain types of soil and their relation to the drift sheets covering the state have incidentally demonstrated that the succession of Pleistocene deposits is more complete and more clearly indicated in Iowa than in any other corresponding area of this continent so far studied. The margin of the Wisconsin drift sheet was traced some years ago by Upham, but until recently this was the only Pleistocene deposit whose boundaries were approximately known. Two sheets of till were differentiated by McGee in northeastern

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Iowa, but it remained for the present survey during the past two years to recognize the southern limits of McGee's upper till. Mr. Bain has pointed out a body of drift below McGee's lower till, and sharply differentiated from it, and Mr. Leverett of the U. S. Geological Survey, has demonstrated the existence of drift in southeastern Iowa, intermediate in age between the lower and upper till of McGee. The Pleistocene history of lowa as now for the first time clearly deciphered includes the following succession of events, each of which has had its influence in determining the present condition and characteristics of Iowa soils.

I. First stage of glaciation, *Albertan.* Invasian of Iowa by glaciers and distribution of lowest sheet of till.

II. First interglacial stage, *Aftonian.* Melting and retreat of glaciers and deposition of gravels, followed by a long period of forest growth, development of soils, and modification of the original drift.

III. Second glacial stage, *Kansan.* Cold more intense and glaciation more general than during the first stage. Distribution of McGee's lower till.

IV. Second interglacial stage, *Buchanan.* Introduced by deposition of gravels in Buchanan, Black Hawk, Floyd, Cerro Gordo and other counties. This stage was very long and the surface of the second drift sheet was profoundly modified by erosion, oxidation and leaching before it came to a close.

V. Third stage of glaciation, *Illinois.* During this stage only a small part of Iowa, embracing portions of Louisa, Des Moines and Lee counties, was invaded by glaciers. The ice came from the northeast, bringing boulders from the eastern shores of Lake Huron.

VI. Third interglacial stage (unnamed), during which the modification of the second drift sheet proceeded over the greater portion of Iowa. The small area occupied by the third deposit of drift also suffered more or less of modification.

VII. Fourth glacial stage, *Iowan.* During this stage the northern half of Iowa was overrun by glaciers. The southern

limit of this incursion may be traced a few miles north of a line drawn from Iowa City to Des Moines, and then deflected northwestwardly to Plymouth county. It was during this stage that the enormous granite boulders so conspicuous in Bremer, Black Hawk, Buchanan and other counties in northeastern Iowa were transported and deposited where they now lie.

VIII. Fourth interglacial stage, *Toronto* (?) This fourth interglacial stage was short as compared with the second, and probably with the third. The amount of erosion, oxidation and leaching that during this interval took place in the surface of the fourth sheet of drift is altogether inconsiderable. The amount of change that has taken place since the beginning of the interval up to the present time is comparatively small.

IX. Fifth glacial stage, *Wisconsin*. The last invasion of Iowa by glacial ice occurred in times so recent, geologically speaking, that the youngest sheet of till exists practically in the condition in which the glaciers left it. The area in Iowa affected by this last invasion is nearly triangular in shape, the base of the triangle coinciding with the north line of the state from Worth to Osceola counties, with the apex located at Des Moines. In the northern part of this area there are numerous stretches of ill-drained lands, the surface is only very gently undulating and the stream channels, where defined at all, have cut only a foot or two into the prairie sod.

X. The recent stage, since the retreat of the Wisconsin ice, brings Pleistocene history down to the present. The recent stage, while long as measured in years, has been too short to produce any appreciable effect in the surface of the Wisconsin drift.

The work of the Iowa geologists in differentiating the Pleistocene deposits and incidentally deciphering Pleistocene history has received the recognition and indorsement of the highest authorities on Pleistocene geology in the United States. Prof. T. C. Chamberlin, chief of the Pleistocene

division of the United States Geological Survey, at various times during the past year, made visits to a number of the typical localities in Iowa and verified the interpretations of the local geologists.

Prof. R. D. Salisbury, also connected with the United States Survey, and in charge of the Pleistocene work of the Geological Survey of New Jersey, accompanied Mr. Bain upon a short trip across the northern portion of the state, going as far west as Sioux City and Rock Rapids. The topographic characteristics of the Iowan and the Wisconsin were studied and the probable equivalence of the drift sheets east and west of the Des Moines lobe was tentatively decided upon. The correlation forms a good basis for the next season's work, and is of particular value because of Professor Salisbury's wide experience in geographic work.

Mr. Leverett spent a considerable portion of the field season in Iowa tracing out the Illinois drift and studying the effect of that invasion upon the drainage of southeastern Iowa. While the work was done for the national Survey the very interesting results have been from time to time communicated to us. This courteous co-operation has been of great value and will greatly lessen the cost of the survey of the Pleistocene deposts of that region when it shall be undertaken. The result of all this combined work on the part of the state and the national Surveys, has been to make Iowa classic ground for the study of Pleistocene deposits.

The Pleistocene deposits not only determine the nature of our soil, but the water supplies for more than half the inhabitants of Iowa are derived from them, and in them the only known permanent gas wells within the state occur. The saving that may be effected by a thorough knowledge of these deposits is sometimes very great. For example the gas that is found in Pleistocene sand and gravel under conditions easily understood, has led persons unacquainted with its origin to infer that a deep well would tap a larger reservoir of this desirable material. Accordingly wells have been

bored at great expense in utter disregard of all the known conditions affecting the generation and storage of natural gas, and the end was loss and disappointment. A very slight acquaintance with the thickness, structure and contents of the Pleistocene would have saved all the expense and disappointment. Lumps and masses of coal occur also as constituents of the drift series and, in not a few instances, these "indications" have led to large expenditure in sinking prospect shafts under conditions that made failure a foregone conclusion.

As already noted in determining the counties to be investigated during the past season, the great importance of the coal beds of the state was recognized and a large share of the survey work has been devoted to their study. In Polk county Mr. Bain has carefully examined the coal horizons already known, with a view of determining the probability of the existence of deeper horizons. In connection with the problem of the influence of the settling of one coal seam upon the formation of the overlying bed, a visit was made by him to the Keb mine of the Whitebreast Fuel Co. near Ottumwa, where a hitherto unsuspected lower coal has been found. The line of investigation seems likely to yield important economic results. In Madison county Professor Tilton, in Dallas Mr. Leonard, and in Guthrie county Mr. Bain, have been tracing in detail the eastern outcrop of the Winterset limestone. The tracing of this limestone is of direct economic interest, since east of it the Des Moines or productive coal measures outcrop. West of it the barren beds of the Missouri stage are the surface formation, and the coal-bearing beds can only be reached by deeper working. Professor Norton's work upon the deep wells indicates that the current estimates upon the thickness of the coal measures of southwestern Iowa are seriously in error, and it is proposed to take up field work in the region within the coming year for the purpose of determining this and other questions. It is a pleasure to recall at this point the accuracy of much of the early geological work in

the state and the way in which predictions made when the geology of the region was so imperfectly understood have since been verified. Thus Worthen*, as a result of work done at Des Moines in 1856, said: "A good supply of a much better quality [of coal] may undoubtedly be obtained by sinking a shaft to the lower seams, which are probably not more than two or three hundred feet below those in the above section." Some years after deeper shafts were sunk, and now there is a large amount of coal mined from these lower horizons. In Guthrie county Mr. St. John†, in speaking of a sandstone found in sinking a shaft at Panora, said: "Beneath the sandstone the horizon of the Lacona coal would be reached probably at a depth of ten to twenty feet, but since the continuity of this bed is known to be interrupted, so that it has the character of a local deposit, we can not with certainty say whether the coal will be found at this locality or not." This is of particular interest, not only from the fact that coal has since been found and is now mined at the level indicated, but from the recognition of the difference between a coal bed and a coal horizon. The location of the coal horizons is properly the work of the geologist, while the finding of the coal bed along that horizon is the work of the prospector. Other instances of predictions which have been verified might readily be cited, but that is aside from present purposes. It is sufficient to state that the continued study of the coal measures is showing that despite their great irregularity there is a certain amount of order in them, and as their study is contined new criteria for structural work are being formulated.

Museum.—The collections of the Survey have continued to grow both by donation and by the efforts of the various members of the force. The museum has been visited by a large number of people, many of whom were strangers and unacquainted with the resources of the state. The displays of

* Hall: Geol. Iowa, Vol. I, p 171. 1858.
† White: Geol. Iowa, Vol. II, p. 109. 1870.

building stones, brick, clay goods, and minerals form an effective advertisement for the state and it is proposed to enlarge them from time to time. The formation of a collection and the building up of a museum is believed, however, to be an incidental rather than a primary function of the Survey, and until the funds appropriated for the survey are enlarged, but little can be spent on museum work.

The office work of the Survey has been carried on as heretofore, except that Mr. Leonard has been in charge the latter half of the year. The drawing has been mainly done by Mr. F. C. Tate, though the map of Johnson county, submitted herewith was prepared by Mr. M. F. Clements, and the Cerro Gordo map by Mr. C. G. Meier. The Marshall map was drawn and engraved by Messrs. A. Hoen & Co., who have previously done work for the Survey. The remainder of the county maps submitted were engraved and printed by the Iowa Printing Co., of Des Moines.

The correspondence of the Survey has been heavy, including as it does numerous requests for identification, estimates and opinions. The exchanging of the Survey reports for those of other surveys or scientific societies, with the acknowledging of the incoming literature, is alone a matter of some considerable labor. This division of the work has been in charge of the secretary, Miss Newman.

During the year the Iowa Survey has profited by numerous courtesies from geologists and organizations in no way directly connected with it. The visits of Chamberlin and Salisbury, and the season's field work of Leverett, in connection with the study of the Pleistocene, have already been noted. A number of strategic points in the state were also visited by Prof. G. F. Wright for the purpose of studying these same deposits. The Survey receives freely the results of the observations of these specialists and the benefit of their judgment.

Within the past few months the old State quarry in Johnson county has yielded remains of a remarkable fish fauna.

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The beds in which the remains occur are of Devonian age, but no such assemblage of Devonian fishes has hitherto been found in North America or, for that matter, in the world. The material has been placed in the hands of Dr. C. R. Eastman, of the Museum of Comparative Zoology, at Cambridge, Mass., and he generously proposes to study the collection and prepare the material for publication without cost to the Survey. Concerning the matter of publication, some joint arrangement whereby a part of the edition may bear the imprint of the Museum of Comparative Zoology, and part that of the Survey can probably be effected to mutual advantage.

The most important work by outside organizations in Iowa is that of the Topographic Division of the United States Geological Survey. Early in the season a party of topographers began work in northeastern Iowa, the object being to complete the topographic map of that portion of the state. Some years ago topographic mapping was begun in eastern Iowan and carried northward from the parallel of 41° 30′. It is now proposed to extend the work to the north line of the state. The importance of this work to the Iowa Survey is difficult to estimate. The district to be covered embraces the part of the driftless area that extends into Iowa. The peculiarities of the area are such that geological work can scarcely be done with any acceptable degree of exactitude without the aid of a topographic base map, and without such a base map geological mapping is practically out of the question. With the completion of the topographic work and the publication of the maps by the United States Survey, the geological work in that interesting region may be prosecuted with success, and with less than half the labor and expense that would otherwise be involved.

General Supervision.—During the past year considerable time has been spent both by Mr. Bain and myself, in general studies, particularly upon the drift, and in field trips with other members of the Survey. It is believed that the best

preparation for making a satisfactory report upon any small area in the state is a preliminary study of regions where the different formations are most typically developed. This has been particularly necessary in taking up the study of the drift since the criteria used in the discrimination of the drift formations are different from those used in other geological work. With this in view the various members of the Survey have, from time to time, made visits to those points in the state where the different formations are best developed.

Individual Work.—My own work, apart from the supervision above noted, has embraced a general direction of survey work, the reading and editing of manuscripts submitted by different members of the force, the answering of endless inquiries by correspondents, the identification of fossils collected in the several counties investigated, and the examination of various materials submitted by citizens of the state with a view of determining their economic value. All this was merely incidental. During the year I have completed the field work in Johnson and Cerro Gordo counties, and have prepared the manuscript reports on these counties, with maps and illustrations. These reports are now submitted as a part of the accompanying volume. The field work was extended into Floyd county. Reports on Buchanan and Delaware counties will soon be ready for submission. A paper has been prepared on Pleistocene Iowa, and another on the state quarry beds in Johnson county. Early in the year some anomalous conditions encountered in boring the Postville well were investigated, and a special paper has been prepared and published on the great stone quarries at Cedar Valley in Cedar county.

During the early months of the year Mr. Bain was mainly employed in the office, his time being principally taken up with supervising the printing of Volume V, which was then going through the press. The field work in Polk county was carried on at the same time and short excursions into various portions of the state were taken for the purpose of making

general correlations. In the spring the determination of the relations of the drift deposit south of Des Moines occupied some time, and in May the Guthrie county work was taken up.

July 1st Mr. Bain was given partial leave of absence, since which time a portion only of his time has been devoted to survey work, Mr. Leonard taking his place in the office. During the remaining months of the year most of Mr. Bain's time, so far as it was devoted to survey work, was spent in Polk and Guthrie counties, the reports upon these areas being submitted herewith. He has spent some time, however, in more general studies of the drift problems of the state in company with Messrs. Chamberlin, Leverett, Salisbury, Tilton, Beyer and Leonard. During the season he made some studies of the soil value of the loess, presenting a paper upon the subject to the State Horticultural Society in November.

Mr. A. G. Leonard began work in June, taking the place of Mr. Bain, in the office. Whenever the conditions in the office have made it possible, Mr. Leonard has spent the time in field work, devoting special attention to Dallas county.

Prof. W. H. Norton has devoted the time that could be spared for work in connection with the survey to completing his report on Artesian Wells. This work proved to be one of much greater magnitude than was at first supposed. The interpretation of the well records is a task requiring a vast amount of conscientious labor, and the correspondence involved in procuring records and giving directions for keeping them, consumed a great deal of time. The report as now presented brings the records to date, but the work of collecting information as new wells are bored in the future should be continued. The expense will be trifling compared with the value of the definite information which well records properly interpreted are capable of affording. Short supplementary reports, bringing the records up to date of publication, may be issued from time to time as occasion seems to warrant.

Dr. S. W. Beyer has devoted such time as he could spare chiefly to work in Marshall county. The work in this county is now complete and the report, suitably illustrated, is submitted as a part of the accompanying volume. Dr. Beyer spent a few days with me in Cerro Gordo county, and in my company he made a visit to the typical outcrop of the Buchanan gravels, the object being to get data for definite comparisons with Pleistocene deposits in Marshall county. He has also the field work in Story county well advanced toward completion.

The work in Madison county was assigned to Prof. J. L. Tilton and has been completed with very great care. The directions for careful studies of the different members of the Madison county section of indurated rocks and included faunas, with a view to using the information in correlating certain coal measure horizons in Iowa with those of other states, were faithfully carried out. Professor Tilton made some trips to typical localities elsewhere for the purpose of collecting data that would aid in the work in Madison. His report on the county, with necessary maps and illustrations, accompanies this report.

Miss Newman has continued to fill the position of secretary and general office assistant; and has performed the exacting duties of the place with such satisfaction and success as to merit special commendation.

I have the honor to remain, gentlemen, with great respect,

Your obedient servant,

SAMUEL CALVIN,
State Geologist.

REPORT OF MR. A. G. LEONARD.

IOWA GEOLOGICAL SURVEY,
DES MOINES, December 31, 1896.

SIR—I have the honor to submit herewith a report of the work done since entering upon my present duties last June. Much of my time during the summer was given to field work. Several weeks were spent in Guthrie county, part of the time in company with Mr. Bain, in studying the drift and Cretaceous rocks of that region. In July field work was commenced in Dallas county and was continued at intervals until the end of the season. Considerable material was collected for a report on the geology and economic resources of the county.

During the last of August and early part of September several trips were taken into Decatur and Clarke counties for the purpose of studying the Missouri or upper coal measure limestone, and also to establish more definitely the eastern limits of the formation. The limestone was studied at Osceola and Davis City in Iowa, and Cainsville, Missouri, and its border located at several points. The limits of the formation had already been determined farther north in Guthrie, Dallas and Madison counties. The value of this stone as a quarry rock makes the determination of its distribution and extent a matter of no little economic importance.

As a preliminary to the study of the drift deposits numerous points of interest in Polk county were visited during the summer. Trips were made to Polk City, Berwick, Mitchellville and the vicinity of High Bridge. A day was spent along

the Skunk river in determining the width and extent of its broad alluvial bottoms. Since the completion of the field season, as well as previously, a portion of my time has necessarily been taken up with the routine work of the office. Considerable progress has also been made in the preparation for publication of the results of investigations in the field.

Very respectfully,

A. G. LEONARD,
Assistant State Geologist.

TO PROF. SAMUEL CALVIN,
State Geologist.

REPORT OF MR. W. H. NORTON.

MOUNT VERNON, Iowa, December 1, 1896.

SIR—I have the honor to transmit herewith the report just completed on the Artesian Wells of Iowa. The scope of the work has already been indicated in my report for the year 1895. During the present year, several months have been given without reservation to this investigation—a much longer time than was considered necessary at the opening of the year. The delay thus caused in the completion of the volume is only in a measure to be regretted; since the report now includes a much fuller treatment of several important topics than otherwise would have been possible, and collates a large amount of most valuable data from wells recently sunk in different parts of the state.

Your obedient servant,

WILLIAM HARMON NORTON.

TO PROF. SAMUEL CALVIN, PH. D.,
Director Iowa Geological Survey.

GEOLOGY OF JOHNSON COUNTY.

BY

SAMUEL CALVIN.

GEOLOGY OF JOHNSON COUNTY.

BY SAMUEL CALVIN.

CONTENTS.

INTRODUCTION.

SITUATION AND AREA.

Johnson county is situated near the southern limit of what is know as the east central part of the state. From Davenport directly west to the west line of this county the distance is about forty miles. Muscatine is, however, the nearest point of importance on the Mississippi river, and this point is only about seventeen miles distant from the southeast corner of Johnson county. Referred to the United States land surveys the county is included in townships 77-81 north, and ranges 5-8 west of the fifth principal meridian. Its area embraces about six square miles more than seventeen congressional townships. In form the county is a square to the southeast corner of which there is appended an area six miles in length from north to south and having an average width of about seven miles. The eastern boundary of the appended area is a continuation of the east line of the square making up the main body of the county; its western boundary follows the winding channel of the Iowa river.

Owing to the location of the territorial capital at Iowa City in 1839, Johnson was one of the first of the interior counties to be settled. A few pioneers had taken up claims here before the capital was located. They had become familiar in a general way with the abundant supplies of building stone which the region was capable of furnishing; and the known geological resources of the region exerted no small influence in determining the site to be chosen for the seat of government for the new territory.

GEOLOGICAL WORK IN JOHNSON COUNTY.

The pioneer geologist, Dr. David Dale Owen, was the first to do geological work in Johnson county and place the results on scientific record. In 1850 he examined the rock exposures at Iowa City. He followed up the Iowa river and noted the natural exposures in its banks to a point beyond the limits of

the same deposit, is characterized by yellow till, large, light-colored granite bowlders, and by the fact that it occupies a low plain when compared with adjacent loess-covered areas which are in general highlands of moderate elevation. A ridge bounding the Solon lobe passes from near the northwest corner of Cedar township to sections 1 and 2 of Graham, from which point it curves back into Cedar, makes a long sweep through sections 35, 34 and 33, and trending northwest passes south of Solon, and on to near the northeast corner of Big Grove township. The Burlington, Cedar Rapids & Northern Railway finds a natural gap through the ridge near Solon and thence follows the margin of the drift plain, with the terminal or interlobular ridge on the one hand and low-lying, level bowlder-strewn fields on the other, until it leaves the county near Ely.

Iowan bowlders are more or less common up to the very foot of the ridge described. They are most common where rain-wash has removed the rich, black loam which is very generally developed on the surface of the Iowan drift. A typical bowlder-strewn area is found north of the Cedar Rapids road in the Nw. qr. of Sw. qr. of Sec. 15, Big Grove township. Within a small space are gathered a large number of masses of gray granite, some of which are twelve to fifteen feet in diameter.

The second lobe is larger and wider than the first. North Liberty is situated well within its area, on a portion that exhibits the typical characteristics of Iowan drift plains in counties farther north. This broad digit-like extension of the Iowan drift will therefore be called the North Liberty lobe. The topography of this lobe has been modified in two ways since its mantle of Iowan drift was deposited. The Iowa river traverses the lobe from west to east and has developed a broad flood plain into which the southern portion of the drift plain gradually blends. North of the river, accumulations of loess of greater or less thickness overlie, in places, the Iowan drift and conceal the physiographic features that, but for their presence, would normally be present. Allowing

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Johnson county. He explored the valley of Rapid creek and made a record of the outcrops along that stream. He recognized the fact that the limestones belong to the Devonian system and that certain sandstones found at a number of places in the county are Carboniferous.*

In 1855 Prof. James Hall began work as state geologist of Iowa, and in the prosecution of his investigations the geology of Johnson county received more or less attention. In Professor Hall's report† there are references to the rock exposures at Iowa City on pages 131-133, and beginning on page 260 a brief space is devoted to the discussion of the geology of Johnson, Linn, Benton and Iowa counties.

Dr. C. A. White, state geologist of Iowa from 1866 to 1869 inclusive, notes some of the geological features of Johnson county in his report.‡ On page 188, vol. I, there is a reference to the "Birds eye" marble which occurs in the Devonian limestone of the county, and on pages 308 and 309, vol. II., there is a brief description of the old "State Quarry" which is located on the Iowa river eight or ten miles northwest from Iowa City. There is also a reference to ancient peat from a Johnson county well on page 402, vol. II.

In his memoir on the Pleistocene History of Northeastern Iowa§ Mr. W J McGee makes frequent reference to the indurated rocks and superficial deposits of Johnson county, and C. R. Keyes‖ in his compilation of the glacial scorings in Iowa, refers to some instances of ice planing near Iowa City.

Besides the official reports noted short papers, each dealing with a restricted range of geological phenomena presented by Johnson county, have appeared from time to time in scientific journals and other publications. Among the authors contributing such papers may be mentioned, Barris, Calvin, Keyes, Shimek, Webster and White.

*Report of a Geol. Surv. of Wis., Iowa and Minn., by David Dale Owen, 1852, pp. 85-89.

†Report on Geol. Surv. of the State of Iowa, vol. 1. 1858.

‡Report on the Geol. Surv. of the State of Iowa, by Charles A. White, M. D., vols. I and II. Des Moines. 1870.

§The Pleistocene History of Northeastern Iowa, by W J McGee, Eleventh Ann. Rept. U. S. Geol. Surv., Part I. Washington, 1891.

‖Iowa Geol. Surv., vol. III, pp. 152-153. Des Moines, 1895.

PHYSIOGRAPHY.

TOPOGRAPHY.

General description.—Johnson county lies within the area of anomalous topographic forms described by McGee*; an area in which drift plain interdigitates with loess ridge; an area in which the rivers go out of their way to avoid low lying plains and cut channels longitudinally through ranges of hills that rise forty, sixty, or eighty feet above broad lowland surfaces that apparently might have been traversed with less difficulty, and certainly would have afforded a shorter and more direct course; an area in which the divides are low and the highlands border the river valleys. The county presents an unusual number of topographic phenomena for the reason that it is traversed by terminal deposits of the Iowan glaciers, deposits forming irregular sinuous ridges that may possibly deserve to rank as moraines. Along the northern border of the county there are therefore some small lobes of the Iowan drift sheet continuous with the gently undulating plains characteristic of regions occupied by deposits of Iowan age in the counties north of Johnson. In the southern part of the county all stream valleys are wider and deeper, and the relief in general bolder than in the drift plains north of the Iowan moraine. The greater age of the Kansan deposit has afforded larger opportunities for the agents of erosion to carve and otherwise modify the surface. Through the northern half of the county the Iowan moraine already noted extends in a series of loops, and forms irregular ridges varying from forty to eighty feet in height. These morainic ridges are composed largely of drift, but they contain more or less sand, and are not infrequently overlain at the summit by loess. A fine yellow sand is a very common constituent of these ridges, and the highest points are sometimes crowned with it. Outside the moraine, and usually blending with it more or less perfectly, are interlobular and sub-marginal deposits of loess of

*Op. cit., p. 231.

considerable thickness, distributed over spaces from two to six miles in width. Where the loess forms deep deposits it exhibits the usual rounded steep sided hills, deep V-shaped ravines and other topographic features that everywhere accompany heavy accumulations of this material (Fig. 1). There are areas in which the loess blends with the older drift

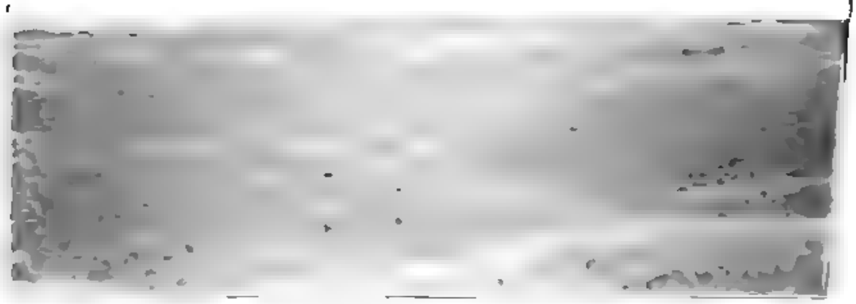

FIG. 1. Loess topography near Iowa City

plains south of the moraine, the loess finally forming but a thin veneer over the surface, and only partly disguising the topographic forms impressed upon the Kansan drift during the interglacial interval. Lastly there are level plains of considerable extent covered with alluvium.

Iowan drift plains.—A few small lobes of Iowan drift extend into the northern part of Johnson county, only two of which, however, are large enough to make an impression worthy of note on the general topography. One of these lobes traverses Big Grove and Cedar townships. The direction of its axis is southeast, and the length, in the county, is approximately ten miles. Solon is situated near one margin, and for this reason this lobe may appropriately be named the Solon lobe. This lobe of Iowan drift, like all other typical areas occupied by

the same deposit, is characterized by yellow till, large, light-colored granite bowlders, and by the fact that it occupies a low plain when compared with adjacent loess-covered areas which are in general highlands of moderate elevation. A ridge bounding the Solon lobe passes from near the northwest corner of Cedar township to sections 1 and 2 of Graham, from which point it curves back into Cedar, makes a long sweep through sections 35, 34 and 33, and trending northwest passes south of Solon, and on to near the northeast corner of Big Grove township. The Burlington, Cedar Rapids & Northern Railway finds a natural gap through the ridge near Solon and thence follows the margin of the drift plain, with the terminal or interlobular ridge on the one hand and low-lying, level bowlder-strewn fields on the other, until it leaves the county near Ely.

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The second lobe is larger and wider than the first. North Liberty is situated well within its area, on a portion that exhibits the typical characteristics of Iowan drift plains in counties farther north. This broad digit-like extension of the Iowan drift will therefore be called the North Liberty lobe. The topography of this lobe has been modified in two ways since its mantle of Iowan drift was deposited. The Iowa river traverses the lobe from west to east and has developed a broad flood plain into which the southern portion of the drift plain gradually blends. North of the river, accumulations of loess of greater or less thickness overlie, in places, the Iowan drift and conceal the physiographic features that, but for their presence, would normally be present. Allowing

for these modifications of the area the North Liberty lobe may be said to occupy the northwestern corner of the county, including all of Monroe, and parts of Jefferson, Oxford and Madison townships. The southern part of the lobe is a low-lying drift plain, merging without break, as already noted, into the broad alluvial valley of the Iowa river. North of the river the plain is somewhat higher and more billowy than on the south. Near the river the hills vary from forty to sixty feet in height. In the western part of Jefferson township, and even more conspicuously in the western part of Monroe township the hills are covered with loess, but for a space of more than four miles in width, almost equally divided between the two townships, there is no loess. The gently undulating drift to the north and northwest grades into slightly bolder, erosional topographic forms as the region approaches the river, and in sections 19 and 20 of Jefferson township there are hills bordering the river valley ninety feet in height, drift covered throughout their entire altitude, with Iowan bowlders projecting from the surface at different elevations, and even showing Iowan till and bowlders of Iowan age on their very summit.

The drift hills just described differ in aspect from the loess covered hills that front the river valley farther east or west. They lack the angularities and unfinished appearance of the loess. The contours are more flowing, the surface is smoother, the grass more luxuriant, the soil is deeper and blacker as is characteristic of drift soils in general.

Like the Solon lobe of Iowan drift, the North Liberty lobe trends southeast. Furthermore it is bounded by loess covered ridges or drift hills rising from forty to ninety feet above the level of the bowlder-dotted plains. The drift in the hills, where exposed, proves to be generally of the Kansan type, very highly oxidized near what was the old surface, with the usual accompaniment of small striated bowlders, and passing downward into the bluish, unoxidized facies of this older sheet of till. Along the northeast side of the lobe the bounding hills trend almost directly northwest-southeast from section 5 of Jefferson

township to section 17 of Penn township. From the point last named the highlands sweep around toward the west, and after traversing sections 24, 23 and 22 of Madison township, they trend northwest, to leave the county finally in section 6 of Oxford township.

A third area of Iowan drift, but of rather small extent, occurs in the northeastern part of Jefferson township. Shueyville is situated at the southern margin of this area. The hills which mark the boundary of the drift plain rise within the limits of the village plat. Immediately west of the village the ridge separating the Shueyville area from the North Liberty lobe, and made up chiefly of Kansan drift, extends northwest to the county line. Southward a series of loess-covered hills rise seventy feet above the drift plain, while eastward the area blends with rather indefinite boundaries into the Solon lobe.

The Shueyville area is continuous with a typical plain of Iowan drift that stretches northward from the village of Western. North of the Johnson county line the three areas described become united into one and merge finally into the great Iowan area that, with readily recognized characteristics, reaches away beyond the northern limits of the state.

The southern part of the North Liberty lobe and the whole area of the Solon lobe are marked by many rounded hills and elongated ridges of sand that owe their origin to events taking place during the period of melting and retreat of the ice. The ridges are in general parallel to the main axis of the lobe in which they lie, and parallel, it may be assumed, to the direction of the ice movement. Their height varies from ten to fifteen or twenty feet.

Kansan drift plains.—More than two-thirds of Johnson county naturally belongs to the area occupied exclusively by Kansan drift. But a broad belt of deep loess extends through the central part of the county south of the margin of the Iowan lobes, effectually concealing the drift surface beneath; and loess, becoming gradually thinner, mantles the surface

and partly disguises the pre-loessial topography all the way to the southern limit of the county. There are areas, however, where loess is absent, or so thin that the physiographic features imposed upon the surface of the Kansan drift during the interglacial intervals may still be ascertained. In the southwestern part of the county, including the valley of Old Man creek and the region south of it, there is a typical area of Kansan drift, only slightly modified by loess. The surface is rolling but the curves are less sharp and the irregularities much less than in the area of deep loess between the valley of Old Man creek and the southern margin of the North Liberty lobe of Iowan drift. The surface shows everywhere the long continued effect of erosion which carved the surface of the old drift sheet into a series of miniature hills and valleys. The valley of Old Man creek has been cut down 100 feet into what was at first a gently undulating drift plain, and the valley has gradually expanded until it is more than half a mile in width. The minor streams have cut valleys of proportionate width and depth, and the whole region exhibits topographic features of much greater maturity than those of areas occupied by Iowan drift.

Scott and Lincoln townships afford another area of the same type. All the county south of a line drawn from east to west through the middle of Scott and Hardin townships may be said to constitute one area exhibiting the physiographic features of the Kansan drift; but through this area the Iowa river has cut a valley from north to south and has developed a broad flood plain with flat alluvium-covered surface that is in striking contrast with the irregularities of the typical drift surface on either side. A few comparatively level areas of Kansan drift, not even yet invaded by the head waters of the smaller drainage streams, occur at certain points, as for example, in the central part of Washington and Scott townships in the western part of Sharon.

Topography of the loess.—Characteristic loess topography is exhibited throughout the broad belt of deep loess which

passes across the middle of the country from east to west; in the interlobular space between the Solon and North Liberty areas of Iowan drift; in a small area in the southwestern part of Monroe township; and in the high bluffs near the Cedar river northeast of the Solon lobe. Relatively to the drift plains, all the regions above mentioned are highlands. The surface is carved into a very intricate system of hills and ravines. The curves are all abrupt, the hills are steep and sharply rounded. The ravines are deep and angular at the bottom, and the surface, where cultivated or disturbed, is gullied and gashed by recent erosion. The transition from the comparatively level drift plains of Iowan age to the ridged and billowy loess is always abrubt, but the physiography of the loess grades without any sharp line of demarkation into the less pronounced erosional forms characteristic of the Kansan drift. In the southern part of the country the loess becomes thinner. In many places erosion has cut through to the underlying drift and reveals the fact that the loess is but a thin veneer moulded over the irregularities of an old deeply eroded surface. In this southern area the loess comes down with nearly uniform thickness upon the sides of the valleys and forms a cap over the crests of the hills. The present surface configuration of the region was developed before the loess was laid down.

River flood plains.—In a few instances the flood plains of the major streams become conspicuous topographic features. In the northeastern part of Cedar township the Cedar river wanders through a broad alluvial plain, two miles or more in width. On the west this plain is overlooked by hills of loess fifty to seventy feet in height. The great plain, followed by the Iowa river from the Iowa-Johnson boundary to where the stream enters a comparatively narrow canyon at the old Roberts Ferry bridge, is one of the most important areas of its kind in the country, and is only excelled in areal extent by the rapidly widening alluvial plain upon which the river enters after emerging from its canyon south of Iowa City.

In Pleasant Valley, Lincoln and Fremont townships this low plain attains a width of many miles, occupying practically all of Fremont township, and uniting with a plain of similar character that includes the lower course of the Cedar river and extends even beyond the Mississippi below Muscatine.

Lake basins.—A few small depressions, kettle holes or lake basins occur in the North Liberty drift plain, near the line along which the drift and alluvium merge into one continuous surface. The basin of Swan lake, which lies chiefly in sections 4 and 5 of Madison township, is the largest of these depressions. Its length is nearly half a mile, and it has an area of about sixty acres. At the period of settlement of the country, fifty years ago, Swan lake was a beautiful little sheet of clear water, twelve to fifteen feet in depth and well stocked with fish. The rim of the lake, superficially at least, is composed of sand and gravel, but the entire depression is mainly hollowed out of the stiff drift clay. For some years Swan lake has been simply a marsh supporting a luxuriant growth of sedges and rushes. The original basin is now largely filled. Rain wash has carried in sand and clay, dust has been blown in by the winds, and the annual decay of rank vegetation has contributed no small amount of peaty matter. The ponds and lakelets that once occupied the numerous other depressions of the region have met the same fate as Swan lake. It is probable that all the depressions here noticed had the same origin and were due to the final melting of detached masses of ice included in the glacial debris.

Anomalous divides.—The Solon drift lobe constitutes one of the anomalous divides so well described by McGee in the work already cited. From this low plain the land rises abruptly, and to a height of nearly 100 feet, in approaching the valley of the Cedar river on the one hand, or the valley of the Iowa river on the other.

Table of elevations.—The following table compiled from Gannett's Dictionary of Altitudes shows the elevation, in feet, above sea level of some of the principal points in the county:

Oxford	745
Tiffin	695
Iowa City, Chicago, Rock Island & Pacific Railway	685
Iowa City, Burlington, Cedar Rapids & Northern Railway	667
Solon	794
Morse	763
Elmira	751
Lone Tree	717

DRAINAGE.

The streams of Johnson county are not very numerous. One master stream, the Iowa river, controls almost the entire drainage of the county. A very small area in the northeastern corner of Cedar township pays tribute to the Cedar river, while in the southwestern part of Washington township the valley of Deer creek is drained into the English river. This last stream, however, while flowing through Washington county is a tributary of the Iowa.

The Iowa river.—Within the limits of Johnson county the Iowa river has a course, counting its numerous sinuosities, of more than fifty miles in length. From Iowa county it crosses into Johnson in section 31, township 81 N., R. 8 W. For more than half the width of the county the general course of the stream is eastward. In section 19, township 81 N., R. 6 W., it turns at right angles to its former course, forming the great elbow so frequently mentioned by McGee,* and thence flows in the main southward, finally forming the western boundary of Fremont township. Before passing Fremont township the general course is changed toward the southeast, and this direction is maintained until the river reaches the low flood plain of the Mississippi.

In the first part of its course, after passing the western boundary of the county, the Iowa river winds back and forth in the broad flood plain already mentioned; but above the iron bridge south of Shueyville it leaves the plain to cut longitudinally through ridges, composed of loess, drift and limestone, that rise nearly 100 feet above the level of the plain from

*Pleistocene History of Northeastern Iowa.

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In the first part of its course, after passing the western boundary of the county, the Iowa river winds back and forth in the broad flood plain already mentioned; but above the iron bridge south of Shueyville it leaves the plain to cut longitudinally through ridges, composed of loess, drift and limestone, that rise nearly 100 feet above the level of the plain from

*Pleistocene History of Northeastern Iowa.

In Pleasant Valley, Lincoln and Fremont townships this plain attains a width of many miles, occupying practically all of Fremont township, and uniting with a plain of similar character that includes the lower course of the Cedar river and extends even beyond the Mississippi below Muscatine.

Lake basins.—A few small depressions, kettle holes or lake basins occur in the North Liberty drift plain, near the line along which the drift and alluvium merge into one continuous surface. The basin of Swan lake, which lies chiefly in sections 4 and 5 of Madison township, is the largest of these depressions. Its length is nearly half a mile, and it has an area of about sixty acres. At the period of settlement of the country, fifty years ago, Swan lake was a beautiful little sheet of clear water, twelve to fifteen feet in depth and well stocked with fish. The rim of the lake, superficially at least, is composed of sand and gravel, but the entire depression is mainly hollowed out of the stiff drift clay. For some years Swan lake has been simply a marsh supporting a luxuriant growth of sedges and rushes. The original basin is now largely filled. Rain wash has carried in sand and clay, dust has been blown in by the winds, and the annual decay of rank vegetation has contributed no small amount of peaty matter. The ponds and lakelets that once occupied the numerous other depressions of the region have met the same fate as Swan lake. It is probable that all the depressions here noticed had the same origin and were due to the final melting of detached masses of ice included in the glacial debris.

Anomalous divides.—The Solon drift lobe constitutes one of the anomalous divides so well described by McGee in the work already cited. From this low plain the land rises abruptly, and to a height of nearly 100 feet, in approaching the valley of the Cedar river on the one hand, or the valley of the Iowa river on the other.

Table of elevations.—The following table compiled from Gannett's Dictionary of Altitudes shows the elevation, in feet, above sea level of some of the principal points in the county

Oxford	745
Tiffin	695
Iowa City, Chicago, Rock Island & Pacific Railway	685
Iowa City, Burlington, Cedar Rapids & Northern Railway	667
Solon	794
Morse	763
Elmira	751
Lone Tree	717

DRAINAGE.

The streams of Johnson county are not very numerous. One master stream, the Iowa river, controls almost the entire drainage of the county. A very small area in the northeastern corner of Cedar township pays tribute to the Cedar river, while in the southwestern part of Washington township the valley of Deer creek is drained into the English river. This last stream, however, while flowing through Washington county is a tributary of the Iowa.

The Iowa river.—Within the limits of Johnson county the Iowa river has a course, counting its numerous sinuosities, of more than fifty miles in length. From Iowa county it crosses into Johnson in section 31, township 81 N., R. 8 W. For more than half the width of the county the general course of the stream is eastward. In section 19, township 81 N., R. 6 W., it turns at right angles to its former course, forming the great elbow so frequently mentioned by McGee,* and thence flows in the main southward, finally forming the western boundary of Fremont township. Before passing Fremont township the general course is changed toward the southeast, and this direction is maintained until the river reaches the low flood plain of the Mississippi.

In the first part of its course, after passing the western boundary of the county, the Iowa river winds back and forth in the broad flood plain already mentioned; but above the iron bridge south of Shueyville it leaves the plain to cut longitudinally through ridges, composed of loess, drift and limestone, that rise nearly 100 feet above the level of the plain from

*History of Northeastern Iowa.

which it turned aside. Even the highest part of the drift that, merging with the flood plain, reaches beyond North Liberty in the normal direction of the stream, is seventy feet lower than the hills through which the indirect, roundabout channel has been cut. At the great elbow it would have required only a few miles of cutting in the direction previously followed to have enabled the river to reach the low drift plain of the Solon lobe, but as if lowlands of Iowan drift were something especially to be avoided the stream abruptly changes its course to the southward to follow the high interlobular loess-covered area, until it finally emerges upon the low alluvial plain south of Iowa City.

Deep farm wells show that the Iowa river, in its course from the west line of the county to where it enters its canyon south of Shueyville, follows closely a preglacial valley that had been excavated to a depth of 150 feet below the present level of the river. The gorge followed by the stream from the iron bridge to Iowa City is comparatively recent, and in large part is probably post-Iowan. At all events the bed and sides of the channel are in places still rocky, and in portions of its course the stream is even now cutting into native ledges of Devonian limestone. South of Iowa City the stream follows an old and very wide gorge that, as shown by a number of borings, was originally 200 feet deeper than the present valley. In some places, and probably throughout its whole extent, the gorge was filled with Kansan drift, and this drift, in the present river valley, is now overlain by eight or ten feet of alluvium.

Clear creek.—The Iowa river receives no very important tributaries within the limits of Johnson county. Clear creek is the first of any consequence received from the west. It rises in Iowa county and follows a general direction a little south of east through Oxford and Clear Creek townships and joins the Iowa in Lucas township near Coralville. From above Tiffin to its confluence with the Iowa, Clear creek flows in a valley that, in its present aspect, has a history reaching back to the

close of the Kansan ice stage. The depth of the valley measured from the higher hill tops is 100 feet and the width varies from a half to three-fourths of a mile. Deep wells again show that parts at least of this valley were scooped out to much greater depths in pre-Kansan time.

An interesting tributary of Clear creek is Buffalo creek, which joins the larger stream a few miles above Tiffin. Buffalo creek drains a part of the North Liberty drift lobe. It has cut through the rim of loess-covered hills which bound the drift plain, but its direction is southwest, at right angles to the normal direction that would have been taken by a tributary of Clear creek, provided the major stream had developed its drainage basin by ordinary processes of erosion. It is doubtless true that, in the long inter-glacial interval between the close of the Kansan and the coming of the Iowan stage, the drainage area of Clear creek was normally developed, with a dendritic system of channels reaching out on either side of the main axis to the margin of the basin. In such a system, in the latitude of Iowa, the greater part of the drainage area would eventually come to lie on the north side of the principal east-west valley. During the Iowan stage the northern part of this normally developed drainage area was invaded by the North Liberty lobe of Iowan ice; and marginal deposits of sand and loess were piled up inside the basin in such a way as to obliterate the regularly developed channels on the north side of the valley. Accordingly the drainage area on the north is reduced to a narrow belt of highlands which is broken through at one point by the erratic course of Buffalo creek. The particular combination of circumstances that determined the direction in which this affluent cuts through the rim of hills and brings its tribute from the low Iowan drift-plain can only be conjectured.

As is also true of streams flowing east or west in the latitude of Iowa, Clear creek follows the southern margin of its valley, close to the foot of the northward facing bluffs. Furthermore the southern wall of the valley is steep, while

that on the north rises with gentler slopes to the more rapidly receding highlands and is more profoundly carved and sculptured by the agents of erosion.

Old Man creek.—Old Man creek drains the southern part of Johnson county west of the Iowa river. Rising in Iowa county it pursues a general eastward course to join the larger stream. Its valley, like that of Clear creek, is deep and wide, and its history dates from the retreat of the Kansan ice. Its drainage area is normal. The natural course of development suffered no interference by the encroachment of Iowan ice, or the accumulation within its area of marginal deposits of loess.

Near its confluence with the Iowa river Old Man creek flows southeast, and its tributaries in this part of its course are themselves eastwardly flowing streams. But where the direction of the main channel is toward the east, the stream flows near the southern edge of its valley. There are steeper bluffs on the south side than on the north. The larger part of the drainage basin lies north of the principal axis. The headwaters of the northern affluents reach to within a mile, or even less than a mile, of the valley of Clear creek; while on the opposite side of the axis, Deer creek and other branches of English river—the next eastward flowing stream south—rise within hailing distance, and restrict the drainage of Old Man creek in this direction to a fraction of a mile.

The region drained by Clear creek and Old Man creek is included in the Loess-Drift Area of McGee.* McGee, however, regards the topography and drainage of the area as related not to a single plane, but to a series of planes, each inclined to the south and uptilted along its northern edge. The eastward flowing stream is, in each case, located near the southern margin of the plane to which it is related, and the steep southern wall of each respective valley is simply the elevated margin of the next succeeding plane on the south.† No description could more felicitously represent the present

*Pleistocene History of Northeastern Iowa, p. 411, et seq.
†Op. cit., pp. 412-413.

aspect and relations of the several drainage basins of the area under consideration. But it seems possible after all to refer the whole system of drainage basins included in the Loess-Drift Area to a single plane, and that plane the original gently sloping surface of the great drift sheet after the retreat of the Kansan ice. This surface, in the region under discussion, was drained by a number of parallel streams, each flowing toward the east. As soon as these streams cut channels of any considerable depth, the two sides of each channel were differently affected by the agents of erosion. The northward facing surfaces suffered less than the opposite side of the channel from the alternations of freezing and thawing and consequent effects of erosion, in early winter and spring. They were less affected by the droughts of summer, which tended to check the growth of vegetation and render the surface more pulverulent and more easily attacked by dashing rain storms. The result was that as the channel was deepened the north side of the valley receded more rapidly than the south, the slopes soon became gradual, the small lateral streams on the north cut back into the highland with greater facility and greater speed, robbing the secondary streams developed on the south side of the next drainage area to the north; and so as a result of normal causes each drainage basin became unsymmetrical and was converted into a sloping plane with the main drainage stream along its southern margin. The east-west streams of the driftless area show similar effects as a result of the same cause, only the effects are modified in consequence of the fact that the stream valleys are cut in indurated rocks in place of the loose materials of the Kansan drift. The northward facing bluffs, however, are steeper than those on the opposite side of the valley. They are generally wooded, or at least are clothed with ranker vegetation that affords protection from atmospheric disintegration. As a result of the larger amount of material carried down from the southward facing slopes on the northern side, the bottom of the valley inclines southward, and the stream runs

close to the foot of the steep bluffs that face toward the north.

In the case of Clear creek and Old Man creek the aspect of the drainage area has in each case been more or less modified by the deposition of loess. As already noted Clear creek basin has suffered more from this cause than the other. In the drainage basin of Old Man creek the loess is simply a thin veneer spread over topographic forms that had practically reached their full present development before the loess was laid down. It is true the loess on the hill tops is usually a little thicker than on the slopes or in the bottom of the ravines, and so, taking no account of erosion of the bottom of the valleys since, the inequalities of the surface seem to have been somewhat accentuated as a result of its deposition; but after all the difference is so small that it may be disregarded, and we may look upon the present surface as essentially what it would have been had there been no deposition of loess.

Pardieu creek.—A small intermittent stream, known as Pardieu creek, begins near North Liberty, cutting its way in a southeast direction through the marginal loess covered ridges surrounding the North Liberty drift plain, and joins the Iowa about two miles above Coralville.

Rapid creek.—From the north and east the Iowa receives few streams of any consequence. Rapid creek is the most important. It traverses the loess belt south of the Solon lobe, cutting through to the Kansan drift, and through the drift down into the Devonian limestone. That part of its channel which lies above the northeast corner of section 36, Newport township, is probably comparatively new. It is in this part of its valley that the stream runs over limestones. The valley may have been made since the loess was laid down.

Sanders creek is a small and very erratic tributary of Rapid creek, that, like its primary, drains a part of the deep loess area south of the Solon lobe. Its history does not antedate the deposition of the loess. Its course is first southwest; then turning at right angles it flows northwest, and when

almost within a stone's throw of the Iowa river it bends sharply to the south to unite its waters with Rapid creek. A high loess ridge causes the sharp bend a mile above its mouth.

All other creeks flowing into the Iowa from the north and east are small. Two breaks in the rim of hills marking the southwestern boundary of the Solon lobe of Iowan drift—one in section 23 and the other between sections 16 and 17 of Big Grove township—permit small streams to carry off the drainage waters from the low drift plain.

A number of small streams, nearly parallel to each other, drain the drift covered areas of Monroe and Jefferson townships. One of the most important of these is Knapp creek that passes diagonally through the western part of Monroe township and joins the Iowa river in section 27, T. 81 N., R. VIII W.

STRATIGRAPHY.

General Relations of Strata.

A number of geological formations outcrop within the limits of Johnson county. The indurated rocks, however, are very generally concealed by the thick mantle of loose materials, in the form of drift, loess and alluvium, which cover the whole surface in some places to a depth of 300 feet. All rock exposures are limited to the northern and northeastern portions of the county. In the absence of such exposures in the southwestern townships the McKinley quarry in Washington county, one-half mile south of the Johnson county line, in Sec. 5, Tp. 77 N., R. VIII W., is important as throwing light on the geological age of the rocks immediately beneath the drift in the adjacent portions of Johnson.

The known geological formations of Johnson county and their taxonomic relations, are shown in the subjoined

[illegible]

[illegible]	[illegible]	SERIES.	[illegible]
		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
			Iowan Till.
			Kansan Till.
	[illegible]	[illegible] or [illegible] Carboniferous.	Des Moines.
		[illegible] or Lower Carboniferous.	Kinderhook.
[illegible]		Upper Devonian.	State Quarry.
	Devonian.	Middle Devonian. (Hamilton?)	Cedar Valley.
			Wapsipinicon.
	Silurian.	Niagara.	Anamosa.
			Le Claire.

Geological Formations.

SILURIAN SYSTEM.

LE CLAIRE LIMESTONE.

So far as known the Le Claire limestone is the oldest geological formation naturally exposed within the limits of Johnson county. A few small outcrops of this limestone occur near the base of the bluff which overlooks the Cedar river in the southwest quarter of the northwest quarter of section 2, Cedar township. A precipitous cliff, exposing the laminated quarry stone of the Anamosa stage, fronts the

river in the northeastern part of section 3 and adjoining parts of section 2 of the township named. The bluff is about half a mile in length, when it gives way at its southeastern end to a low plain which is a part of the alluvial lowlands extending for some miles on both sides of the stream. The small exposures of Le Claire limestone referred to are seen at intervals from twenty to thirty rods back from the river near the foot of the hill where it faces the low plain and trends nearly at right angles to the stream. The Le Claire limestone is here a very fine grained, hard, highly crystalline dolomite, light buff or cream in color. The several exposures indicate a thickness of about twenty feet. No fossils were seen. The reference of the rock to the Le Claire stage is based on lithological and stratigraphical grounds alone. As usual with the thoroughly dolomitized and crystalline beds of this horizon, the rock would make a very superior quality of white lime.

ANAMOSA LIMESTONE.

Characteristic beds of the Anamosa stage overlie the Le Claire limestone in the bluffs already noted in sections 2 and 3 of Cedar township.

FIG. 2. View in the old McCune Quarry, Anamosa Limestone, Cedar Township, Johnson County, Iowa.

This exposure of Anamosa stone is about forty feet in thickness. The upper thirty feet is not divided into definite layers, but it splits readily along the planes of lamination into smooth-surfaced slabs of any desired thickness. In this part of the exposure there are many concretions of chert. In most respects it agrees with the upper white limestone of the quarries at Stone City.

In the lower part of the bluff the stone is a yellow, earthy, rather coarse dolomite, more definitely divided into layers, free from lamination and therefore showing no tendency to part except along the planes of bedding. In lithological characters these lower layers resemble the building stone beds of Anamosa age at Le Claire, in Scott county. The ledges of non-laminated stone at the base of the exposure range from four to eleven inches in thickness. A complete section of the bluff, not all exposed, however, at any one place, would give the following.

		FEET.
5.	Arenaceous, light colored loess	2 to 4
4.	Pebbly drift, containing a large number of bowlders from one to three or four feet in diameter. Probably of Kansan age	4 to 6
3.	Laminated bed of Anamosa limestone without definite partings, with many lenticular and irregular concretions of chert	30
2.	Yellow, non-laminated ledges of Anamosa limestone from four to eleven inches in thickness	10
1.	Hard, light colored crystalline dolomite of Le Claire stage	20

The laminated quarry stone of this locality has been known and, to a moderate extent, utilized for more than half a century. It is to this locality that Owen evidently refers in speaking of the source of the material used for gravestones by the pioneer stonecutters of Iowa City.* Owen, however, locates the exposure in the south part of township 82 N., R. V W., in place of in its true position in the north part of township 81, and instead of referring the strata to the Silu-

*Report of a Geol. Surv. of Wis., Iowa and Minn., p. 84. Philadelphia, 1852

rian he includes them in his description of the limestones of Red Cedar, etc., belonging to the Devonian.

Lack of facilities for transportation has prevented the development of quarrying and lime burning industries in connection with these exposures of Anamosa and Le Claire limestone.

BERTRAM AND COGGAN BEDS.

In the counties of Jones and Linn the Anamosa limestone is succeeded by a coarse, irregularly bedded, earthy or non-crystalline dolomite that Professor Norton has called the Bertram limestone.* The beds of Bertram limestone are again succeeded in Linn county by what the same author calls the Coggan beds.† The Coggan beds are composed of "soft, buff, magnesian, fossiliferous limestone," and with the deposition of this limestone the record of the Silurian in Iowa is brought to a close. No representatives of either Bertram or Coggan beds have been seen in Johnson county.

DEVONIAN SYSTEM.

WAPSIPINICON STAGE.

Otis and Independence beds.—In Linn and Cedar counties—and probably the same is true of most other counties in which the contact of Silurian and Devonian occurs—the magnesian limestones of the Niagara series are followed by non-magnesian limestones and shaly beds of the Devonian. Immediately above the Coggan beds, where the series is complete, there lies a fine grained, drab colored limestone, called the Otis limestone, and this is succeeded by the shales and shaley limestones of the Independence shales. Both Otis and Independence beds belong to the Wapsipinicon stage as defined by Norton.‡ Neither Otis nor Independence beds, however, are known to be exposed in Johnson county. The lowest member of the Devonian series observed in

*Iowa Geol. Surv., vol. IV, p. 135. Des Moines, 1895.
†Ibid, p. 138.
‡Op cit., p. 156.

natural exposures is the brecciated phase of the Wapsipinicon stage which is well illustrated at Solon in Big Grove township. The geographical area within which outcrops of Bertram, Coggan, Otis and Independence strata might be expected to occur, the area between the cliff of Anamosa limestone on the Cedar river and the outcrops of breccia at Solon, is deeply covered with drift. No stream valleys cut down to the underlying rocks. Indeed, in portions of this area the rocks do not come within 200 feet of the surface. A well drilled on the farm of Mr. J. A. Henik in section 17 of Cedar township reached rock at a depth of 222 feet, and other deep wells in the same neighborhood show the same great depth of the superficial deposits. This region, or at least a part of it, seems therefore to be occupied by a preglacial valley over which the limestones and shales were cut away, probably down to the Delaware stage of the Niagara.

The Fayette breccia.—Southwest of the exposures of Niagara limestone on the Cedar river the first rocks seen in place occur at Solon and belong to the brecciated phase of the Wapsipinicon stage. This phase is typically illustrated in the great railway cut at Fayette, for which reason McGee has called the formation the Fayette breccia. The breccia occurs within the corporate limits of Solon and in the surrounding neighborhood. The characteristics and various phases of this zone, as they appear in Linn county, have been very fully described by Norton.*

Forty rods north of the center of section 24, Big Grove township, and the same distance from the northeast corner of the original town of Solon, the road cuts through ledges of breccia that correspond to Norton's first and second stages. On the whole, beds corresponding to the second stage predominate. The rocks are made up of angular fragments of very fine grained, gray or drab limestone lying in all possible positions in a softer, lighter colored, gray matrix. Some of the fragments are homogeneous throughout and break with

*Iowa Geol. Surv., vol. IV, p. 157. Des Moines, 1895.

conchoidal fracture; some are very finely laminated and tend to split along the lamination planes. No fossils occur in this portion of the breccia either in the matrix or in the embedded fragments.

The streets in the northern edge of Solon pass over ledges of breccia which illustrate Norton's second and third phases of this formation. The phase exhibiting the fine-grained, drab colored fragments is overlain by the phase in which the fragments are lighter gray or buff in color and coarser and more granular in texture. The embedded fragments of this third phase contain well preserved specimens of *Atrypa reticularis*, *A. aspera*, *Orthis iowensis* and *Pentamerus* (*Gypidula*) *comis*.

On the Cedar Rapids road, in the western edge of Solon, there are exposures of beds partly brecciated that occupy a position geologically higher than the beds just described. The fauna is more extensive and includes the following: *Dolatocrinus* (sp. und.), *Favosites alpenensis*, *F. placenta* or a closely related species differing chiefly in the mode of growth, *Stropheodonta dimissa*, *Orthis macfarlanei*, *Spirifer pennatus*, *Atrypa reticularis*, *A. aspera*, *Rhynchonella intermedia* and *Pentamerus comis*. Besides the species mentioned there are casts of a large gastropod, probably a Platystoma, and an undetermined species of Gomphoceras. The strata at this point are very much shattered, the bedding planes are obliterated, oblique joints intersect the beds and divide the mass into numberless shapeless pieces from a few inches to a foot or more in diameter, the color ranges through various shades of light brown, yellow and gray, and the texture is coarse and granular. The stone is quarried and used for building purposes to a limited extent. The beds here correspond well with the fourth stage of the brecciated zone as described by Norton. They are geologically equivalent to the *Spirifer pennatus* beds of Buchanan county.

On the low hill which rises above the level of the beds described, there are numerous weathered coralla of *Phillips-*

astrea billingsi. and *Acervularia davidsoni*. The corals are not in place, but are parts of the residual products resulting from the decay of strata that normally lie above the level of the horizon exposed in the roadway. At Independence, Troy Mills and other typical localities Phillipsastrea occurs immediately above the *Spirifer pennatus* zone, and *Acervularia davidsoni* occupies a position from ten to fifteen feet higher.

Twenty rods west of the point just considered there is another exposure on the south side of the road. The beds here have a strong local dip toward the east, and the west end of the exposure shows the fine grained drab fragments, free from fossils, characteristic of the lower phases of the brecciated zone.

There are some exposures of the Fayette breccia on the headwaters of Rapid creek, the most important being that which occurs on the farm of Mr. J. Beecher, near the northeast corner of section 22, Graham township (T. 80 N., R. V W). Here the rocks have been quarried to a considerable extent. The phase represented is No. 4, of Norton. In some of the beds the brecciation is more complete than any seen at the corresponding horizon near Solon. The fauna includes the small Favosites that has been provisionally referred to *F. placenta*, together with *Orthis iowensis*, *Atrypa reticularis*, *A. aspera*, and *Pentamerus comis*. This is the most easterly exposure of Devonian rocks in Johnson county, the most easterly exposure, indeed, of any kind in this direction until the ledges of Niagara limestone are encountered along the Cedar river in Cedar county. Between the Beecher quarry and the exposures of Niagara on the Cedar, there extends the same preglacial valley that separates the Devonian outcrops near Solon from the cliffs of Niagara limestone in section 2 of Cedar township.

The southwesterly dip of the strata, if uniform, would carry the breccia below the succeeding members of the Devonian series in passing down the valley of Rapid creek; but the strata have been thrown into a series of low folds (Fig. 3),

and so at a few points in the axes of the anticlines the breccia is revealed farther down the creek. The most instructive exposure due to the cause mentioned was seen in the Se. qr.

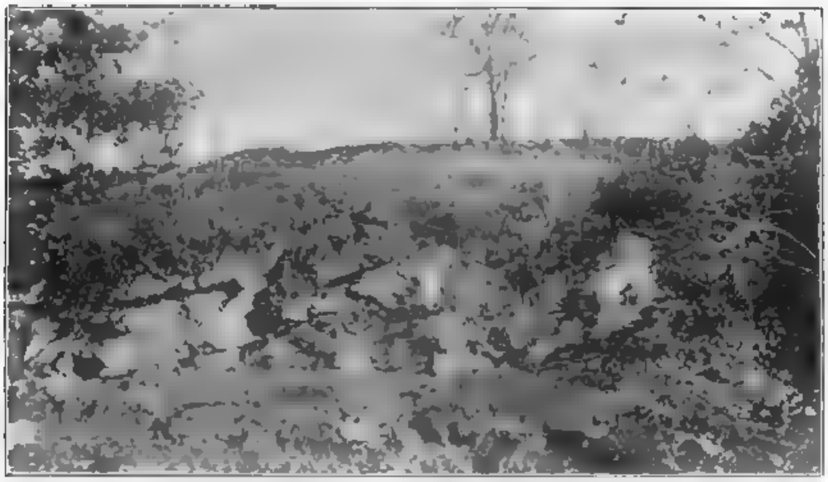

FIG. 3. Local dip due to folding of Devonian strata. South bank of Rapid creek Section 20, Graham township.

of the Ne. ¼ of Sec. 20, Graham township. Here the fold is quite sharp, the strata dipping from the axis on either side at an angle of fifteen degrees. The cliff at this point is higher than usual, and in the axis of the fold shows the following section.

		FEET.
3.	Evenly bedded, rather soft, shaly limestone, yellowish in color, capable of being quarried in large slabs; characterized by many small individuals of *Atrypa aspera* and numerous body plates and segments of stems of *Megistrocrinus farnsworthi*.	6
2	Hard rock, not shattered or brecciated, few fossils, a number of coralla of *Phillipsastrea billingsi* in a single layer near the middle of the bed, and a large celled species of Alveolites	8
1.	Fourth phase of brecciated zone, imperfectly bedded, rock hard but very much shattered, and divided into small angular pieces by oblique joints. Fauna contains *O. this iowensis*, *Atrypa reticularis*, *A aspera* and *Pentamerus comis*.	12

In this section number 1 belongs to the Wapsipinicon stage, while numbers 2 and 3 represent the Cedar Valley stage of the Devonian. Owing to the sharpness of the fold the Phillipsastrea beds descend below the level of the creek a few rods east of the axis, and the Megistocrinus beds attain a thickness of fifteen feet.

THE CEDAR VALLEY STAGE.

All the limestone beds in Iowa of Devonian age, at least all lying between the Independence shales and the Lime Creek shales, have been grouped under the name of Cedar Valley limestone by McGee* and Keyes.† Norton,‡ however, places the Fayette breccia, including the *Spirifer pennatus* beds, together with the Independence shales and the Otis limestone, under the Wapsipinicon stage. According to this arrangement the Cedar Valley stage begins with the coral-bearing horizon overlying the *Spirifer pennatus* beds.

The characteristics of the Cedar Valley limestone, as developed in Johnson county, are best illustrated in the following sections.

TYPICAL LOCALITIES AND EXPOSURES.

The exposure which most clearly shows the contact of the Cedar Valley with the Wapsipinicon stage is that already described in the northeast quarter of section 20, Graham township. The Phillipsastrea beds, number 2, and the Megistocrinus beds, number 3, of that section belong to the Cedar Valley, while the brecciated beds, number 1, belong to Norton's Wapsipinicon. The Megistocrinus beds are well exposed at many points farther down the creek, their last appearance along this stream occurring near the northeast corner of section 36, Newport township.

Near Solon, along a small creek that flows through the northern part of section 26, Big Grove township, there are several small quarries worked in the Megistocrinus beds.

*Eleventh Ann. Rept. U. S. Geol. Surv., p. 814.
†Iowa Geol. Surv., vol. I, p. 34.
‡Iowa Geol. Surv., vol. IV, p. 157.

The layers are soft, shaly, and in color vary from light gray to yellow. They are intersected by oblique joints which, however, do not interfere with quarrying out blocks of considerable size. The bedding is parallel. The fauna includes *Phacops rana* Green, two or three species of Platyceras or Capulus, *Stropheodonta demissa* Conrad, *Orthis iowensis* Hall, *Spirifer pennatus* Owen, *Spirifer subundiferus* M. &W., *Atrypa reticularis* Linne, *A. aspera* Scloth., *Megistocrinus farnsworthi* White, *Aulocophyllum princeps* Hall, Acervularia related to *A. davidsoni* as that species is generally recognized, *Favosites alpenensis* A. Winchell, or a related species, a hemispherical species like *F. emmonsi* Rom., and *Astræaspongia hamiltonensis* M. & W. The beds in these quarries are equivalent to the Megistocrinus beds of the preceding exposure. The *Atrypa aspera* is small as is usual in beds of this horizon. The Megistocrinus, Aulocophyllum, small *A. aspera* and Astræaspongia are the most characteristic forms of the Megistocrinus fauna.

At Eicher's quarry, located in the left bank of the Iowa river in northwest quarter of section 27, Newport township, the following section is exposed.

	FEET.
9. Brown limestone, with crinoid stems, a Cladopora related to the form described by Hall as ***Striatopora rugosa***, but having the branches and polyp tubes very much smaller, and a large coarsely ribbed variety of ***Atrypa reticularis***	4
8. Drab granular limestone, no fossils	8
7. Coral reef composed chiefly of coralla of ***Acervularia davidsoni*** E. & H., but containing many coralla of Favosites and Ptychophyllum	2
6. Moderately hard bed with crinoid stems, ***Spirifer parryanus***, ***Atrypa reticularis***, Favosites, Cyathophyllum, Cystiphyllum, etc.	1½
5. Shaly limestone with many small crinoid stems, ***Chonetes scitula*** Hall, ***Spirifer parryanus*** Hall, ***Tentaculites hoyti*** White, and ***Monticulipora monticola*** White	1½
4. Hard ledge with many small crinoid stems, Cladopora, Ptychophyllum and some large coralla of Acervularia	2

		FEET.
3.	Yellow shaly bed with Atrypa, Orthis, etc	2
2.	Yellow and gray shaly limestone, without fossils	13
1.	Moderately hard limestone, intersected by a number of oblique joints, light colored, laminated, with many stem segments and some perfect calyces of Megistocrinus and other species characteristic of the Megistocrinus fauna. Megistocrinus beds	15

At the Hutchinson quarry (figure 4) on the west side of river at Iowa City, the section exposed shows —

		FEET.
11.	Loess	2 to 6
10.	Kansan drift	8
9.	White limestone, fine grained, breaking with conchoidal fracture, containing in places many casts of *Straparollus cyclostomus* Hall	12
8.	Rather fine grained, grayish limestone, crowded in some places with stems of *Idiostroma cæspitosum* Win.	2
7.	Gray, earthy, granular limestone	6
6.	Irregularly bedded limestone in rather thick layers with many included coralla of Acervularia, Stromatopora, Idiostroma, etc	10
5.	Hard, grayish-blue limestone, weathering yellow, in ledges 6 to 10 inches thick, quite free from fossils.	5
4.	Coral reef (No. 7 of Eicher's quarry)	2
3.	Bluish-gray limestone	4
2.	Dark colored bed with many corals, Cystiphyllum, etc.	1
1.	Blue limestone, in heavy ledges, 1 to 2 feet in thickness, with *Atrypa reticularis, Spirifer parryanus*	6

Numbers 1 and 2 of the Hutchinson quarry section are equivalent to numbers 5 and 6 at Eicher's, while number 5, though only five feet in thickness, is equivalent to 8 and 9 of the Eicher quarry. At the Eicher quarry the uppermost member of the section is still below the Idiostroma horizon, which is represented by number 6, of the Hutchinson section. About one-half mile east of Eicher's quarry, in the valley of Sanders creek, the Idiostroma beds, with their characteristic crinkled coralloid stems, are well exposed. The channel of the creek cuts down to the coral reef bed, number 7 of Eicher's, number 4 of Hutchinson's. Between the two bridges at Iowa City an

in oceanic currents attended by rapid elevation or depression of temperature, earthquake shocks even, or concentration of sea water in a temporarily isolated basin, would be competent to produce the observed result. Whatever the cause, it was effective, and every square yard of sea bottom received its quota of dead fishes.

Several genera and species are indicated amid the profusion of fish remains interred in this old cemetery. One of the most common forms is the well known Devonian type, Ptyctodus. Teeth of this genus are sometimes literally crowded together to form a sort of fish tooth conglomerate. These teeth or tritors vary in size and shape, and in the degree of wear to which they were subjected before the death of their owners; but in the opinion of experts to whom they have been submitted, they probably all belong to the single species *Ptyctodus calceolus*. Along with Ptyctodus are remains of one or more species of Devonian Placoderms, as indicated by great numbers of imperfect dermal plates. The Dipnoan genus Dipterus is represented by a number of the interesting wing-shaped teeth characteristic of this very old but persistent type; and there are teeth evidently related to Dipterus, but so different as probably to make generic separation necessary.

But more interesting than all the rest, and far outnumbering the teeth that could at first sight be referred to Dipterus, or to related genera, is a vast assemblage of teeth of varying shapes and dimensions, that bear a striking external resemblance to the crushing teeth of certain genera of Lower Carboniferous sharks. In the opinion of Dr. C. R. Eastman, however, it is doubtful if there are any Selachian teeth in the entire lot. He finds that, microscopically, so far as sections have been made, they are all identical in structure with the teeth of Lung fishes or Dipnoans. They seem indeed to be primitive Dipnoans, exhibiting a stage of evolution not far removed from the point whence the Dipnoan and Elasmobranch type diverged; and their careful study will doubtless throw much light on the nature of the relationships existing

This quarry has been worked for some years by Mr. Gilbert Irish. The section, below a thin bed of loess and Kansan till, shows—

		FEET.
8.	Hard, ferruginous, reddish brown sandstone of Des Moines stage, Upper Carboniferous	6
7.	Whitish-gray, fine grained limestone	8
6.	Idiostroma beds, containing as usual many massive stromatoporoids and some coralla of Acervularia	15
5.	Heavy tough ledge of limestone	4
4.	Bluish-gray limestone, weathering yellow, containing large, coarse ribbed Atrypas and the small branched, small celled Cladopora found at same horizon in Eicher's quarry	8
3.	Bluish-gray limestone in two ledges, first ledge containing many crinoid stems	4
2.	Coral reef equivalent to 4 of Hutchinson's and 7 of Eicher's	2
1.	Bluish beds with great numbers of broken, crushed, detached valves of *Spirifer parryanus* and the robust, large celled Cladopora (*C. iowensis* Owen sp.) described as *Striatopora rugosa* by Hall	2

The coral reef bed of the preceding sections is very constant throughout the county. The reef is made up chiefly of coralla of *Acervularia davidsoni* E. & H., with which are associated *Ptychophyllum versiforme* Hall, *Favosites alpenensis* Winchell, and a Favosites resembling *F. emmonsi* Rominger, but differing from it only in having the tabulæ complete. The reef is preceded by beds containing *Spirifer parryanus* Hall, and *Cladopora iowensis* Owen. It is followed by beds that are at first barren, but which generally, a few feet above the reef, become fossiliferous and yield the large coarse ribbed *Atrypa reticularis* and the small unnamed Cladopora of the same type as *C. iowensis*. Lithologically the beds above the reef are different in different localities. In some places they are hard bluish-gray limestone, in other places, partly on account of weathering, they are yellow limestone, and in still other localities they present the appearance of yellow calcareous shale.

A few rods southeast of the bridge over Rapid creek, near the northeast corner of section 36, Newport township, the coral reef is seen extending across the wagon road. All the exposures between that point and the headwaters of the creek near Elmira lie below the coral reef horizon. The most easterly exposures, as already described, belong to the brecciated phases of the Wapsipinicon stage. This same coral reef, with the same association of beds, lithologically and paleontologically, above and below it, occurs as far north as Littleton in Buchanan county.

Between Linder's boat house and the bridge at Butler's landing, sections 33 and 34, Penn township, the rock exposures in south bank of river embrace all the strata between the Cystiphyllum and *S. parryanus* beds beneath the coral reef, and the white, fine grained limestone at the top of the sections in the Hutchinson and Sanders quarries. The coral reef occurs in the bed of a small wash west of the boat house, and in following it down the river it rises higher and higher above the water. It here affords specimens of *Acervularia davidsoni* of exceptional beauty and perfection. The white limestone at the top of the bluff was formerly used extensively for lime burning. The upper surface of this hard, fine grained limestone retains glacial scorings which, as usual in this vicinity, have an average direction of south 63° east. Some portions of this limestone are much shattered and show a tendency to brecciation.

In the northeast quarter of the northwest quarter of section 21, Penn township, there is a rock-walled ravine which leads down to the river in the northeast quarter of the same section, and exposes the full series of beds from a few feet below the coral reef to the top of the white limestone. The corals are here distributed through a greater thickness of rock than at the other localities described, and are associated with large specimens of *Spirifer parryanus*, the coarse ribbed *Atrypa reticularis* and *Pentamerella dubia*. The white limestone and part of the Idiostroma bed were formerly made

into lime to a limited extent. The lime kiln at this point, however, has for some years been abandoned.

A short distance east of the locality above described, in the bluff forming the left bank of the river, there is an exposure extending for more than half a mile above the mouth of Turkey creek. Turkey creek has here cut a valley 150 feet in depth, and up this valley for some distance there are exposures of the same beds seen in the bluff facing the river. In the river bluffs as well as in the bluffs of its tributary, the rocks are largely concealed by talus, and hence it is impossible to make a section in detail. At the upper end of the river bluff, however, almost directly south of the center of section 18 in Newport township, the strata at the level of the water contain *Phillipsastrea billingsi* and *Acervularia profunda*. We have here the lowest member of the Cedar Valley stage. About seven feet of the Phillipsastrea bed are exposed. The bed does not show definite stratification, and it breaks up, on weathering, into small angular chips.

The Megistocrinus beds follow, as usual, those containing *Phillipsastrea*. They are regularly stratified and the effect of the weather breaks them up into large slabs or plane-surfaced blocks. Some layers are heavy, hard, and capable of furnishing good quarry stone. Others are soft, shaly, yellowish in color and agree well with the common phase near Solon and along Rapid creek. The usual fossils occur, *Orthis iowensis* being in some places unusually abundant. Above the Megistocrinus beds the rocks are shaly as at the Eicher quarry, and the hill slope is covered with talus. Among the loose material are many weathered coralla of *Acervularia davidsoni*, along with species of Favosites, Idiostroma and other forms, all of which belong to higher horizons. Seventy feet above the level of the river, near the south end of the bluff, a ledge seen in place contained *Acervularia davidsoni*, and in the bluff facing Turkey creek, eighty feet above the level of the valley, there is an abandoned lime kiln, near which is an old quarry showing the Idiostroma bed overlain

by white, fine grained, horizontally bedded limestone. Between the base of the Phillipsastrea beds and the summit of the white limestone there occurs the whole thickness of the Cedar Valley stage as it is developed in Johnson county.

The quarry north of the iron bridge, in section 25 of Jefferson township, shows some modifications of the succession of strata occuring farther down the river. The following is the section at this point.

		FEET.
10.	Loess	2 to 10
9.	Pebbly drift, Kansan	3
8.	Decayed limestone, with bowlders of disintegration embedded in highly oxidized dark reddish-brown residual clay	3
7.	Light colored, evenly bedded, fine grained white limestone	10
6.	Coral breccia, composed of coralla of Acervularia, small cylindirical Favosites, a peculiar Diphyphyllum, a very elongated Cyathophyllum, Idiostroma and massive stromatoporoids	5 to 8
5.	Reef of closely crowded masses of Acervularia	2
4.	Regular heavy layers of fairly good quarry stone, containing coralla of Acervularia and Favosites sparsely distributed	5
3.	Blue limestone in layers from 6 inches to 2 feet thick, composed of fragments of crinoids and broken shells of brachiopods	7
2.	Shale and shaly limestone	1½
1.	Heavy blue limestone with concretions of pyrites	2

Spirifer pennatus occurs in the lower part of number 3. In the upper part are *S. parryanus* and *S. asper*. Number 4 contains, besides the corals, *Dielasma iowensis*, *Pentamerella dubia* and a Conocardium. No. 5 seems to be the coral reef bed of the sections near Iowa City with the layers between the Acervularia reef and the Idiostroma bed omitted. No. 6 is the Idiostroma bed, but it is here very much richer in true corals, such as Favosites, Cyathophyllum, Diphyphyllum, and Acervularia, than usual. Nos. 7 and 8 together represent the white limestone with which the normal Devonian sections of the county terminate.

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At the railway quarry, on land belonging to Mr. E. Clark, in the west bank of the river north of Coralville, beds equivalent to the upper part of the sections already described, are exposed. Beneath the overlying loess and drift the following strata occur.

		FEET.
5.	White limestone	12
4.	Stratum crowded with casts of *Straparollus cyclostomus* Hall	1½
3.	Limestone weathering into thin fragments, containing some specimens of Idiostroma and colonies of a cylindrical Favosites	4
2.	Gray limestone crowded with Idiostroma and other stromatoporoids. This with No. 3 represents the Idiostroma beds of preceding sections	8
1.	Hard blue limestone, containing some large coralla of Acervularia	4

At the state quarries on the west side of the river in section 5, of Penn township, the Cedar Valley limestones are exposed near the base of the river bluffs and in the sides of the small tributary valleys. One of these valleys, in the left bank of which there are three or four quarries which may be called the south quarries of the state quarry stone, gives a complete section from the upper part of the Megistocrinus beds to the white, fine-grained limestone with which the Cedar valley stage terminates in this locality. Near the river the beds contain the stem segments of crinoids, the *Atrypa aspera* and the broad *Orthis iowensis* of the Megistocrinus zone. For a short distance, following the ravine back from the river, the beds are not well exposed, but thirty rods from the mouth of the valley the beds show the horizon of *Spirifer parryanus*, above which the coral reef bed is typically developed, and this is followed by yellow shaly limestone. Further up the valley exposures are found at intervals. One-half mile back from the river the Idiostroma bed occurs in sides and bottom of the small creek channel, and is followed normally by the white fine-grained limestone. A thin layer above the Idiostroma zone is crowded with shells of *Strap-*

arollus cyclostomus. The beds, as they successively appear in the creek in following up the ravine, give the normal section of the Cedar valley stage and nothing more. That section does not include the quarry stone of the state quarries. In the bluffs along the river front the quarry stone rests on the Megistocrinus bed, but in the secondary valleys its base rises in the bluffs more rapidly than the bottom of the ravine ascends, and within less than one-half mile back from the river it entirely disappears. The beds constituting the state quarries are a local deposit, and do not belong to the Cedar valley section.

From the several sections and exposures described the general section of the Cedar valley stage may be constituted.

GENERAL SECTION, CEDAR VALLEY LIMESTONE.

		FEET.
11.	White, fine-grained limestone, brecciated in upper part. Fossils rare except in bed near base, which is sometimes crowded with shells of *Straparollus cyclostomus*	20
10.	Upper Idiostroma bed of Hutchinson quarry. This bed is not everywhere separated from the lower bed No. 8	2
9.	Gray, limestone, resembling No. 11	6
8.	Bed with large stemmed Idiostroma, spherical stromatoporoids, some colonies of Acervularia and many small cylindrical forms of Favosites	10
7.	Beds varying much in different localities, usually shaly and yellow in color after exposure to weather	5 to 10
6.	Coral reef	2
5.	Bed with numerous small crinoid or cystidean stems, *Cladopora iowensis* Owen, and *Strobilocystites calvini* White—Nos. 5 and 6 of Eicher's quarry	3
4.	Blue quarry stone in most quarries, with *Cystiphyllum conifolle*. *Cyathophyllum robustum*, Ptychophyllum and Acervularia. Nos. 3 and 4 of Eicher's quarry	4 to 8
3.	Beds varying locally, usually without fossils, No. 2 of Eicher's quarry	12 to 20
2.	Megistocrinus beds, typically developed in the quarries one and one-half miles southwest of Solon, and along Rapid creek in sections 20 and 21, Graham township	15
1.	Phillipsastrea beds	8

shales belonging to the Des Moines stage. Deposits of this stage were once general over the whole area, but erosive agents have swept them nearly all away, and it is only in a few favored localities that they have been protected and preserved. During the time represented by the Lower Carboniferous (Mississippian) series the northeastern part of the county was dry land and subject to subaerial erosion. With the retreat of the Kinderhook sea the whole county became subject to the same influences. As the land rose higher and higher above sea level, deep valleys were cut in Devonian and Kinderhook strata. During the Des Moines stage of the Carboniferous, however, the county was part of a great area of subsidence over which the sea eventually returned and spread sheets of coal measure shales and sandstones. The erosion valleys were filled, and the highlands may even have been covered with Carboniferous sediments. Denudation has long since stripped off these sediments except where they were protected in the pre-Carboniferous valleys.

The Iowa City outlier.—There are two principal areas of coal measure deposits in Johnson county. The first begins in the northern part of Iowa City and extends beyond the middle of section 3 in Lucas township. It occupies an old valley that, as ascertained by borings, was more than eighty feet in depth. The residence of Mr. Euclid Sanders stands almost directly over the center of the valley. The right wall of the valley is seen at the Sanders quarry below the old mill where coal measure deposits overlap eroded edges of Devonian strata. (Fig. 8.) The left wall is seen in Sanders' pasture, thirty rods east of the barn. The coal measure beds end abruptly and their place is taken by the white limestone of the upper part of the Cedar Valley stage. The left wall was at this point more precipitous than the right, for only a few rods away a shaft made in prospecting for coal went down from forty to sixty feet without striking limestone.

North of the old Terrill mill there are two exposures of shaly sandstone belonging to the Iowa City Carboniferous

are a brachiopod coquina having the interstices completely filled with crystalline calcite.

Near the middle of the formation the rock consists of thick ledges which, some years ago, were worked extensively. (Fig. 6.) From these beds came the large limestone blocks used in the foundation of the new state capitol. Although

FIG. 6. View in the State Quarry, Section 5, Penn township. A man stands in front of the principal ledge from which the limestone blocks used in the foundation of the present state capitol were obtained. Some of the rejected blocks in the foreground contain considerable quantities of chert with which are associated great numbers of fish teeth.

the ledges show no definite lamination, and split as readily in one direction as another, the weathered surfaces on opposite sides of the numerous joints often show obscure signs of oblique bedding. The material was evidently swept into place by moderately strong currents.

The ledges worked in connection with the building of the new capitol are the heaviest afforded by the formation. The lowest one is four feet in thickness. It is made up of rather finely triturated brachiopod shells, the most common species being *Atrypa reticularis*. This bed, it seems, did not furnish satisfactory material for it was quarried only to a limited extent. The ledge furnishing the greater number of available blocks lies directly above the first. It is five feet in thick-

of this region these beds were quite extensively quarried for building stone, but their tendency to discoloration and to split into thin laminæ on weathering led to their disuse. At the residence of Mr. Sanders the beds are quite shaly, and contain a thin layer of coal varying from half an inch to an inch or two in thickness. In the pasture of Samuel Hess, south of the Sanders pasture, there are beds of shale, too thin to be of use, but of excellent quality for the manufacture of pottery or paving brick.

The old valley in which the Iowa City outlier occurs has a direction east of south, cutting through the Hess pasture and the pasture next on the south. It passes under the high hill in the northern part of Iowa City, and has been re-excavated in part by the present valley of Ralston creek.

A shaft dug on the land of Mr. Hess showed the following section.

		FEET.
6.	Loess	6
5.	Shale and shaly rock	40
4.	White sandstone	2½
3.	Shale	3
2.	Sandstone	5
1.	Limestone (Devonian)	10

Number 1 is Devonian, numbers 2, 3, 4 and 5 belong to the Des Moines stage of the Carboniferous.

The Amana outlier.—The second body of Carboniferous deposits in Johnson county is on land belonging to the Amana society and may be called the Amana outlier. This outlier begins in the salient bluff that occupies the angle between the Iowa river bottom and the valley of Knapp creek, in section 27 of Monroe township. From this point it continues westward in the bluffs facing the river into Iowa county. The deposit is here a heavy bedded, and often cross bedded, sandstone, composed of coarse grains of silica imperfectly cemented with iron oxide and calcium carbonate. The colors are dingy red and brown with some darker purplish streaks. The rock has been quarried at various points, and one of the

quarries recently worked is near the mouth of Knapp creek. The following secton is there exposed.

		FEET.
5.	Loess and till	6 to 8
4.	Sandy shale	1
3.	White sandstone	½
2	Heavy-bedded sandstone	10
1.	Talus down to creek	15

Small patches of Carboniferous deposits are found at intervals along the Iowa river, and there are some in other parts of the county. One on Rapid creek in section 30, Newport township (Tp. 80 N., R. V W.) is mentioned by Owen,* and McGee† notes the common occurrence of small outliers along the Iowa river, between Iowa City and the great elbow of the stream at the north end of Penn township. Some of these are seen on the top of the bluffs in the neighborhood of the state quarries.

Fossils.—The coal measure beds of Johnson county have yielded few recognizable fossils. Plant remains may reasonably be expected to occur in the shaly portions of the formation, but in these no recent excavations have been made. Certain sandstone beds of the Iowa City outlier near Terrill's mill have furnished specimens of Lepidodendron and Calamites.

PLEISTOCENE SYSTEM.

The surface of Johnson county is very generally covered with Pleistocene deposits. These include an older and a younger drift sheet, a bed of loess and, along the stream valleys, beds of alluvium.

KANSAN DRIFT.

All the known drift in the southern half of the county belongs to the Kansan age. There may be a pre-Kansan drift sheet beneath the Kansan, for throughout the greater part of Iowa the Kansan drift records not the first, but a second ice invasion which spread glacial detritus over an older sheet of

*Owen's Geol. Surv. of Wis., Iowa and Minn., p. 87. 1852.
†Eleventh Ann. Rep U. S. Geol Surv., p. 309. Washington, 1891.

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bridge over Turkey creek in section 23, Newport township; and another body of the same stone occurs in rather puzzling relations to the Megistocrinus beds in section 23, Big Grove township, southwest of Solon. At the last named locality Rhynchonella or Pugnax, is the prevailing fossil. The very fossiliferous limestone seen near the base of the quarry south of Shueyville is of a very different character and belongs to a different horizon.*

Taxonomic relations.—As already intimated, the taxonomic relations of the State Quarry stone are not very clear. At first it seemed that it might possibly represent local deposits made contemporaneously with the Cedar Valley beds, but later investigations indicate that it is younger than the Cedar Valley and was laid down on a deeply eroded surface. In support of this view it may be noted that at the mouth of the ravine below the south quarries in section 5 of Penn township, the State Quarry stone rests on the Megistocrinus beds of the Cedar Valley stage. In following up the ravine the quarry stone rises higher and higher in the bluffs and soon disappears, while the members of the normal Cedar Valley section appear successively in the bottom of the creek. The contact of the two formations cannot, however, be definitely traced. On Rapid creek in section 20 of Graham township, the relations are nearly the same; the State Quarry stone occurs only a short distance above the Megistocrinus beds. At Solon the equivalent of the State Quarry stone occurs on the west side of a small ravine, while on the east side of the ravine, only four or five rods distant, the typical Megistocrinus beds, wholly different in character and with an entirely different fauna, occur at the same level. The quarry beds at the last named locality are composed largely of shells of Pugnax (Rhynchonella). They extend westward along the north side of the valley of a small creek for about one-eighth of a mile and then suddenly disappear, their place in the low bluff being taken by the normal Megistocrinus beds of the

*McGee: Tenth Census Rept. vol. X, Quarries and Building Stone, p. 262.

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quarries recently worked is near the mouth of Knapp creek. The following secton is there exposed.

		FEET.
5.	Loess and till	6 to 8
4.	Sandy shale	1
3.	White sandstone	½
2	Heavy-bedded sandstone	10
1.	Talus down to creek	15

Small patches of Carboniferous deposits are found at intervals along the Iowa river, and there are some in other parts of the county. One on Rapid creek in section 30, Newport township (Tp. 80 N., R. V W.) is mentioned by Owen,* and McGee† notes the common occurrence of small outliers along the Iowa river, between Iowa City and the great elbow of the stream at the north end of Penn township. Some of these are seen on the top of the bluffs in the neighborhood of the state quarries.

Fossils.—The coal measure beds of Johnson county have yielded few recognizable fossils. Plant remains may reasonably be expected to occur in the shaly portions of the formation, but in these no recent excavations have been made. Certain sandstone beds of the Iowa City outlier near Terrill's mill have furnished specimens of Lepidodendron and Calamites.

PLEISTOCENE SYSTEM.

The surface of Johnson county is very generally covered with Pleistocene deposits. These include an older and a younger drift sheet, a bed of loess and, along the stream valleys, beds of alluvium.

KANSAN DRIFT.

All the known drift in the southern half of the county belongs to the Kansan age. There may be a pre-Kansan drift sheet beneath the Kansan, for throughout the greater part of Iowa the Kansan drift records not the first, but a second ice invasion which spread glacial detritus over an older sheet of

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of this region these beds were quite extensively quarried for building stone, but their tendency to discoloration and to split into thin laminæ on weathering led to their disuse. At the residence of Mr. Sanders the beds are quite shaly, and contain a thin layer of coal varying from half an inch to an inch or two in thickness. In the pasture of Samuel Hess, south of the Sanders pasture, there are beds of shale, too thin to be of use, but of excellent quality for the manufacture of pottery or paving brick.

The old valley in which the Iowa City outlier occurs has a direction east of south, cutting through the Hess pasture and the pasture next on the south. It passes under the high hill in the northern part of Iowa City, and has been re-excavated in part by the present valley of Ralston creek.

A shaft dug on the land of Mr. Hess showed the following section.

		FEET.
6.	Loess	6
5.	Shale and shaly rock	40
4.	White sandstone	2½
3.	Shale	3
2.	Sandstone	5
1.	Limestone (Devonian)	10

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till. But the older till, so far as known, is not exposed at the surface within the limits of Johnson county. Its presence, however, seems to be indicated by an unstratified blue clay beneath a black, friable soil with woody fragments, in McGee's well record, No. 172.* The well referred to is located in section 1 of Graham township. The blue till above the soil and forest bed is probably Kansan. Yellow till recorded as occurring above the blue, may be either Iowan or upper oxidized Kansàn, and the sandy beds at the surface belong to the age of the loess.

The Kansan drift, which is the only drift known in all the southern part of the county, is usually overlain by loess, but the loess and the drift upon which it lies are separated by a long interglacial interval. At numberless points the loess has been removed by erosion, and the Kansan drift is exposed. The surface of the drift was very much modified by meteoric agencies, and by the growth of plants before the loess was laid down. In the first place it was very deeply eroded, as is indicated by the fact that the loess forms a relatively thin veneer of nearly uniform thickness over the ridges and ravines of a rather bold erosional topography, which had been fully developed before any loess was deposited. In the second place, during the interglacial interval, the superficial materials of the Kansan drift were very completely oxidized. The drift of this stage was at first a blue clay, and is so still at depths below the influence of oxidizing agents. But at and near the surface the ferrous oxide of the blue clay was changed to the red and brown oxides, with the effect that beneath the loess the Kansan till is dark reddish brown in color. The original drift was rich in lime carbonate, and at moderate depths it retains all of this constituent that it ever possessed, but as a third change to be noted as occurring before deposition of loess, the superficial part of the deposit had the calcareous matter completely removed, partly by growth of plants and partly by the leaching effects of meteoric waters. Fourthly,

*Eleventh Ann. Rept., U. S. Geol. Surv., p. 534.

within the zone subject to the effect of modifying agents, all bowlders of certain kinds of granite suffered decay. They crumble under slight force into a coarse sand; many, especially near the surface, are now represented by masses of incoherent particles distributed through finer glacial debris.

Natural sections showing the reddish brown oxidized zone of the Kansan drift overlain by loess, charged with disintegrated granite bowlders, and having its line of contact with the loess conforming to the inequalities of the present surface and maintaining essential parallelism with it, occur at numerous points along the roadways in the southern part of the county. One of these exposures is found in the west side of a small valley near the northeast corner of section 30 of Lucas township. Another of equal significance is seen south of the bridge over Old Man creek near Windham. Along the west and south sides of section 10 in Washington township there are several good exposures of the same kind. There are in fact scores of similar exposures in Washington, Sharon and other southern townships, one of the most instructive being seen on the county line eighty rods east of the southwest corner of section 33, and another near the northeast corner of section 19, both in Washington township. In Scott township there are excellent sections showing the same phenomena. A railway cut near the northeast corner of section 7, and a number of cuts in the wagon road which follows the south line of sections 1 to 5 will serve as examples. All the cases are consistent, and all support the view that a very long interval elapsed between the deposition of the Kansan drift and the laying down of the loess which, to a large extent, prevented further change.

As already intimated the Kansan drift was originally a blue clay. The bowlders of the Kansan are small when compared with those of the Iowan till. Specimens exceeding four feet in diameter are very rare, and it is seldom that any portion of the bowlders project above the surface of the thick sheet of drift. The Kansan bowlders are very largely dark colored,

fine grained varieties of trap, though there are many small light colored granites, and occasionally one finds numerous transported fragments of limestones, sandstones or other sedimentary rocks. Of the included pebbles and bowlders, unusual numbers are planed and striated on one or two sides, a fact which indicates that, notwithstanding the great thickness of the Kansan deposits, a large part of the material was transported during all, or part of its journey, as subglacial drift.

Glacial scorings.—There are a few points in the county where the Kansan drift rests on planed and scored ledges of limestone. In general it is the hard, brittle, fine grained white limestone in the upper part of the Cedar Valley stage that has preserved the glacial markings. Such markings occur at the summit of the Hutchinson quarry and at points between the quarry and the upper bridge west of Iowa City. At the site of the old woolen mill on Clear creek the rocks in the bottom of the stream are very beautifully planed (Plate I), and at the lime quarry of Mr. Linder, two miles northwest of Iowa City, the white limestone retains the glacial striæ. The direction of the striæ is essentially the same at all the points observed, the main movement of the ice being south 63° east.

IOWAN DRIFT.

The younger drift sheet exposed in Johnson county is known as the Iowan. It is limited to the northern part of the county, and is especially interesting for the reason that, so far as it appears in this county, it was deposited by the extreme southern, lobulate margin of the Iowan ice. Two lobes of this ice sheet, pushing out beyond the average limit, invaded Johnson county and deposited typical Iowan drift in two distinct areas which, in the description of the topography of the county, have been called respectively the Solon lobe and the North Liberty lobe. The limits of these beds have already been described. The Iowan drift differs from the Kansan in a number of particulars. It is not covered by

GLACIAL PLANING ON DEVONIAN LIMESTONE. CLEAR CREEK, WEST OF IOWA CITY.

loess. Its surface has suffered but little erosion since it was deposited. The rolling country south of the Iowan margin, carved as it is into a series of rounded hills and steep-sided ravines, is in marked contrast with the very gently undulating surface of the Iowan drift, where the waterways have cut but a few feet below the general level, and an unbroken plain stretches away to the horizon. Between Coralville and North Liberty the distance is some six miles, but in passing from the first to the second village the road winds for more than two-thirds of the way among loess covered hills and deep gorge-like valleys that illustrate the topography of the Kansan area where it is covered with a thick mantle of loess. But a mile and a half south of North Liberty the loess ends abruptly, the steep hills and deep valleys are left behind and the roadway leads out upon a drift plain that as yet has scarcely been attacked by the agents of erosion. The transition is so sudden as to create surprise. It is like passing into a new country.

The plain upon which the road enters south of North Liberty is occupied by prosperous farms with black, mellow easily cultivated soil. Beneath the soil there is a yellow till which shows scarcely any evidence of change since it was laid down. Oxidation is not more marked at the surface than in the deeper parts of the deposit. Calcareous matter is about as abundant at the grass roots as it is ten feet lower down. The bowlders are sound and hard, showing no signs of decay. Furthermore the bowlders are of gray granites with very few if any of fine grained, dark colored trap. Not many of the bowlders are planed or scratched, and there are scarcely any fragments of transported sedimentary rocks.

The margins of the Iowan drift lobes in Johnson county are marked by hills that rise from forty to eighty feet above the level of the drift plain. These moraine-like hills have already been described in discussing the topographic features of the county.

THE LOESS.

This is a deposit of fine glacial silt evidently derived from the Iowan drift. In Johnson county it is distributed in regions that lie beyond the margin of the area that was covered by Iowan ice. With the exception of the paha of McGee it is very unusual to find loess anywhere in any considerable amount, very far within the territory occupied by Iowan till. The hills that mark the marginal limits of the Iowan ice sheet are everywhere deeply covered by this deposit, and all the remaining portions of the county outside the Iowan drift lobes were overlain to a greater or less depth by the same material.

General description.--The loess of Johnson county is a part of the extensive deposits of this material distributed over certain areas in eastern Iowa. In some particulars it is quite distinct from the loess of the Missouri river valley. With respect to Iowa, therefore, there are two distinct phases of loess, one of which may be called the eastern loess, the other the western. Where typically developed this eastern loess is a yellow clay mixed with particles of silica too fine to be denominated sand, and containing a considerable amount of disseminated calcium carbonate. In Johnson county, however, the deposit is very variable in composition. In the hills that were heaped up around the margin of the Iowan ice, the loess often contains a large percentage of sand. This sand may be gray in color and may make up more than half the deposit as is particularly true in the neighborhood of Solon, and in parts of the low morainic hills which extend southeastwardly from Solon to section 36, of Cedar township. More frequently the sand is finer, bright yellow in color, and mixed with a greater proportion of the typical loess clay. This phase of the sand is well illustrated at numerous points, as, for example, in sections 8, 17, 21 and 22, of Big Grove township, and in sections 10 and 30, of Penn. Then again the materials first transported from the margin of the Iowan ice and deposited over the extra marginal surfaces were coarser than those

transported later, for at the base of the deposit, for some distance from the source of supply, there is usually a sandy layer underneath finer and more typical loess. This sandy layer, which constitutes the sub-loessial sand of Norton, is not found, however, more than a few miles beyond the margin of the Iowan drift.

Genesis.—That the loess is a silt derived from the finer materials of the Iowan drift is supported by the color and composition of the deposit, by its geographical relations to the margin of this drift sheet, and by its superposition sometimes on Iowan till and sometimes on eroded and oxidized surfaces of Kansan till. The nature of the agents whereby it was transported and deposited is not so clear. Some beds of the deposit may possibly indicate transportation from dried and dusty surfaces by wind; but the thick body of loess piled up around the margin of the Iowan drift, with accompanying sands near the source of supply and finer silt carried to greater distances, seems to be best explained by assuming sluggish currents from the melting ice sheet as the agent of distribution and deposition. To summarize the facts relating to the distribution of the coarser and finer materials of the loess it may be stated that at a distance greater than six or seven miles from the margin of the Iowan drift the whole sheet of loess is composed of fine silt; the greater the distance from the margin, the less yellow and more ashen in color the deposit becomes; the sub-loessial sands overlain by true loess are limited to a belt around the drift lobes three or four or five miles in width; and in the moraine-like hills contiguous to the drift margin the entire thickness of the loess from base to surface is frequently arenaceous.

Fossils and other contents.—Since the deposition of the loess some segregation of its limy constituent has taken place, and calcareous concretions known as loess-kindchen are more or less common in typical portions of the formation. In some fine clayey beds vertical "pipes," apparently due to deposition of iron oxide in successive laminar sheaths around long

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whatever, and there are other places where the deepest wells reported have failed to penetrate the entire thickness of the superficial deposits. In the central part of Cedar township wells are bored to a depth of 200 to 225 feet before reaching the indurated rocks, while at Solon, on one side and McCune's quarry in sections 2 and 3 of Cedar township on the other, the rocks come to the surface. There is here evidence of a preglacial, rock-walled valley 200 feet in depth. The plain through which the Iowa river flows from the west line of the county to the iron bridge, has deposits of river sand and gravel 150 feet in depth. The loess and drift in the southeast corner of Scott township have an aggregate depth of 200 feet as shown by well borings, and a well at Lone Tree, Fremont township, was bored through alluvium and drift to a depth of 212 feet without reaching the bottom of the Pleistocene. At Oxford, and other points in the valley of Clear creek, the Pleistocene beds reach a depth of 256 feet, and south of Frytown, in Washington township, a well is reported 282 feet deep without encountering anything but loose, superficial materials.

THE PREGLACIAL SURFACE.

Combining the evidence from well records and known rock exposures, it is seen that the preglacial surface of the county was very irregular and was diversified with deep valleys and rocky, precipitous hills, as a result of a period of erosion immediately preceding the distribution of the first glacial drift. The drift sheets, which aggregate in some places 300 feet in thickness, leveled up the irregular surface by filling the valleys with glacial detritus. Only in a comparatively few cases do even the preglacial hilltops project above the surface of the thick mantle of unindurated loess and drift. The obliteration of the preglacial hills and valleys by the distribution of loose surface materials, has contributed much to the convenience and success of every citizen of Iowa.

SOILS.

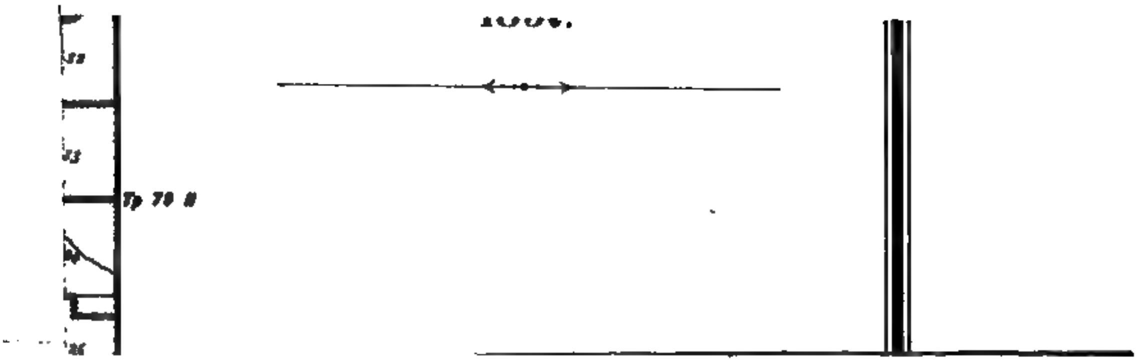
The soils of Johnson county may be arranged in four divisions between which will be found in some instances numerous intergradations.

1. The soil of the Iowan drift lobes is probably the most distinct of any of the divisions. It is typically a rich, mellow black loam of great depth, easily tilled and very productive. Evidences of thrift and prosperity abound throughout the region over which the Iowan drift is deposited.

2. Kansan drift overlain by a thin veneer of loess constitutes the second type of Johnson county soils. This type is best developed south of Old Man creek in Washington, Sharon and Liberty townships; but excellent examples of it are found throughout Scott township and in the northern part of Lincoln. This soil is exceptionally fertile and responds most generously to the labors of the farmer. It has at least one advantage over the soils of the Iowan drift lobes in that it is free from the great numbers of granite bowlders which sometimes encumber farms located on Iowan drift. The elegant homes, large, overflowing barns, well kept stock, and all possible labor saving devices, that are seen on every hand where this soil exists, attests its great productiveness when the labor of the farm is directed by quickened intelligence.

3. Alluvial soils occupy a considerable area within this county. The distribution of alluvium has already been noted. Some parts of the alluvial plains in the northern part of the county are rather sandy, but in general the soils of these plains rank with the best. As a rule they are warm, mellow, rich in plant food, and thoroughly underdrained by reason of the beds of gravel which usually occur at no great depth from the surface. The largest areas of alluvial soils occur in Oxford, Madison, Pleasant Valley and Fremont townships.

4. A fourth type of soil occurs in the heaped up ridges around the margin of the Iowan drift and in the region of



deep loess which is found for a distance of three or four miles south of the margin. Loess is of course the prevailing material constituting the soils of this type, but near the margins of the drift lobes there is more or less of sand. A sandy ridge extends from Solon southeast to section 2, of Graham township. Sand mixed with loess clay occurs in all the marginal ridges around the Iowan lobes, but the greater part of the area has soils composed of typical loess. The region is very much broken and rolling. No vegetable mould develops over the loess ridges. The yellow loess clay is turned over by the plowshare, and to one accustomed to the rich black loam of the drift covered areas the fields present a very uninviting and barren appearance. Loess is rich in lime carbonate and some other substances utilized by plants, so that where the surface is comparatively level good crops are produced though at relatively great expenditure of time and labor. On the steeper slopes, however, that some persist in cultivating, the soil washes badly, the surface is gashed and furrowed by every rain, great irregular ditches excavated by erosion are not infrequent, the crops are poor and thin, and the labor involved in cultivating the soil is excessive as compared with the reward. Small, uncared-for, unpainted houses, ungrassed dooryards, straw covered sheds, and the few implements of husbandry that have been laboriously gathered together wasting in sun and rain for lack of shelter, are characteristic of the hilly regions covered by deep loess.

Deformations.

No marked deformation of strata indicative of folds affecting any considerable thickness of the crust have been observed in Johnson county. There are, however, numerous small local folds in both the Wapsipinicon and Cedar Valley stages of the Devonian. Some of the best examples of such local plications occur along Rapid creek in sections 20 and 21 of Graham township. Others are found near Solon, and quite a number occur between the Robert's Ferry bridge and Iowa City.

Some of the folds are probably due to inequalities of deposition. Strata increase rapidly in thickness when traced in certain directions, and again they feather out completely. Lens-shaped masses of no great horizontal extent are sometimes intercalated between certain beds that elsewhere are in contact, a fact well illustrated at an abandoned quarry south of that now worked by G. R. Irish on the property of Euclid Sanders. The strata laid down on the uneven surface exhibit a number of flexures that simulate true folds.

Unconformities.

There are two striking cases of unconformity among the indurated rocks of Johnson county. The first occurs between the Cedar Valley and State Quarry stages of the Devonian. Between these two stages there is a record of an erosion interval heretofore unsuspected in the Devonian of Iowa. The Cedar Valley beds belong to the Middle Devonian. The State Quarry limestone, with its types of Chemung and Catskill faunas, must be correlated with the Upper Devonian. The second case of unconformity exists between Devonian limestones and Carboniferous shales and sandstones of the Des Moines stage. The erosion interval preceding the deposition of the Des Moines sediments was much longer than that between the Cedar Valley and State Quarry stages of the Devonian. During this last interval the land stood probably higher than at present, for the gorge in which the Des Moines shales and sandstones at the home of Euclid Sanders were laid down descends sixty feet below the channel of the present river.

The indurated rocks are overlain unconformably by the earliest drift; the Iowan drift is unconformable on the Kansan, and the loess is conspicuously unconformable with the Kansan drift upon which it lies throughout all the region south of the limit reached by the Iowan ice.

ECONOMIC PRODUCTS.

Building Stones.

Anamosa stage.--The exposure of Anamosa limestone, Niagara series, in sections 2 and 3 of Cedar township has been quarried since the early settlement of the county. In the upper part of the exposure the rock is very finely laminated, without definite bedding planes, through a thickness of thirty feet. The stone is, however, easily split along the planes of lamination, and so it is possible to take out smooth-surfaced blocks of almost any desired dimensions. There is more or less chert along some of the planes in the upper part of the quarry. Below the laminated portion, down to the level of the river, there are ten feet of definitely bedded, non-laminated ledges, from four to eleven inches in thickness, capable of affording good material for many kinds of masonry. The productiveness of this quarry is checked by lack of facilities for transportation.

The Wapsipinicon stage.—Brecciated beds of the Wapsipinicon stage of the Devonian are quarried at Solon and at the Beecher quarry near Elmira. The stone from these quarries is used to supply a rather limited local demand.

The Cedar Valley stage.—There are numerous small quarries in beds belonging to the Cedar Valley stage, but none are worked on an extensive scale, and none at present are engaged in shipping stone beyond the limits of the county. Still it must be said that the aggregate amount and value of the stone annually taken from these quarries is very great. The blocks from certain beds are easily shaped with the hammer and are well adapted to rough surfaced ashlar and rubble work. For cellar walls, foundations, and all ordinary masonry a large area of country is dependent on the product of quarries in this stage of the Devonian.

The Megistocrinus beds, No. 2 of the general section (p. 71) are quarried along Rapid creek in sections 20 and 21 of Graham township. The same beds have been worked even

more extensively a mile and a half southwest of Solon. In the lower part of the Eicher quarry the Megistocrinus beds were worked. Hard ledges of this zone from which large blocks of excellent quality, with parallel surfaces, might be quarried, occur near the upper end of the bluff above the mouth of Turkey creek, in section 15 of Newport township.

The Hutchinson quarry on the west side of the river at Iowa City works the beds of the general section numbered 4 to 11 inclusive. During the working season this quarry employs from six to eight men. The product is used chiefly in Iowa City, but a considerable amount of it is taken to the country to be used in foundations for barns and other structures.. The best building stone comes from the lower part of the quarry. The Sanders quarry south of the old mill near Iowa City furnishes annually a large amount of rock which finds its market in the towns and farming communities of the county. The ledges furnishing the most serviceable stone lie above number 6 of the general section. The material from the uppermost beds comes out in rather shapeless blocks, but a large amount of it is used for rip-rap in the immediate vicinity of the quarry.

The Crowley quarry in the channel of the river south of the old bridge at Iowa City, works only a few beds, including some below and some above the coral reef, number 6. The aggregate thickness of the beds does not exceed ten or twelve feet. The quality of the stone is the same as from corresponding beds in other quarries.

The quarry near the Iron bridge, two and one-half miles south of Shueyville, has been worked by different persons for a number of years. The stone is in general of the same quality as that furnished by the quarries near Iowa City, rather superior if there be any difference, but suited only for such structures as may be built of stone shaped roughly and quickly with the hammer. In this quarry the beds numbered 8, 9, and 10 in the general section are blended into one, and this single bed is exceedingly rich in true corals such as

Acervularia, Cyathophyllum, Diphphyllum and Favosites. Idiostroma and other stromatoporoids are abundant, but they are not so prominent as in the corresponding beds farther south.

The railway quarry north of Coralville furnishes stone of the same quality as that from the other quarries of the Cedar Valley stage, the best product coming from the firm blue ledges above the coral reef, number 6 of the general section. The McCollister quarry in section 22, Lucas township, is worked in rather light-colored beds between the coral reef and the stromatoporoid horizon number 8. Numerous other quarries have been operated temporarily at this horizon, the work being done in each case to supply the immediate needs of some small neighborhood, or probably of only a single farm. The aggregate annual value of the building stone, taken from this stage is large, but the work is distributed among many quarries. In none is the equipment very expensive. The ledges are loosened up by blasting, and afterwards broken by sledges into pieces convenient to be handled without hoisting machinery.

The State Quarry stage.—The beds of the State Quarry stage are capable of furnishing a building stone that in point of durability and ease of cutting is unexcelled. The rock resists the action of the weather admirably. The ledges vary from a few inches to five feet in thickness, and thus furnish a wide range of choice, so far as dimensions are concerned. The state quarries are located in section 5 of Penn township, in the west bluff of the Iowa river. They were first worked in connection with the building of the old capitol at Iowa City. They were worked even more extensively to furnish blocks for the foundation of the new capitol at Des Moines. Among the products of these quarries are bases for heavy monuments, blocks for bridge piers, curbstone, crossing-stone, and stone for ordinary building purposes. The finer grained ledges, composed of thoroughly triturated shells of brachiopods and skeletal parts of crinoids, afford good material for cut stone of the best grades.

more extensively a mile and a half southwest of Solon. In the lower part of the Eicher quarry the Megistocrinus beds were worked. Hard ledges of this zone from which large blocks of excellent quality, with parallel surfaces, might be quarried, occur near the upper end of the bluff above the mouth of Turkey creek, in section 15 of Newport township.

The Hutchinson quarry on the west side of the river at Iowa City works the beds of the general section numbered 4 to 11 inclusive. During the working season this quarry employs from six to eight men. The product is used chiefly in Iowa City, but a considerable amount of it is taken to the country to be used in foundations for barns and other structures.. The best building stone comes from the lower part of the quarry. The Sanders quarry south of the old mill near Iowa City furnishes annually a large amount of rock which finds its market in the towns and farming communities of the county. The ledges furnishing the most serviceable stone lie above number 6 of the general section. The material from the uppermost beds comes out in rather shapeless blocks, but a large amount of it is used for rip-rap in the immediate vicinity of the quarry.

The Crowley quarry in the channel of the river south of the old bridge at Iowa City, works only a few beds, including some below and some above the coral reef, number 6. The aggregate thickness of the beds does not exceed ten or twelve feet. The quality of the stone is the same as from corresponding beds in other quarries.

The quarry near the Iron bridge, two and one-half miles south of Shueyville, has been worked by different persons for a number of years. The stone is in general of the same quality as that furnished by the quarries near Iowa City, rather superior if there be any difference, but suited only for such structures as may be built of stone shaped roughly and quickly with the hammer. In this quarry the beds numbered 8, 9, and 10 in the general section are blended into one, and this single bed is exceedingly rich in true corals such as

The products of the quarries near Iowa City have been used extensively in macadamizing the public streets, and recently a large amount of crushed stone has been employed in making concrete foundations for brick paving. In the absence of available gravels it can only be a question of time until the use of macadam is extended to the clayey thoroughfares outside the cities. Throughout most of the northeastern half of the county stone for macadamizing the country roads will be found in convenient locations and inexhaustible abundance.

Ornamental Stone.

The corals embedded in the different zones of the Cedar Valley limestone are, in most cases, preserved in such a way as to render them available in the manufacture of paperweights and other small objects for which stone taking a high polish may be used. The articles so made are very attractive, and the annual value of the product is not inconsiderable. The original structure of the corals is perfectly preserved, and infiltrated calcite fills the pores, rendering the whole compact and in condition to receive a very beautiful polish. These polished corals have long been known as Iowa City marble. The species available for the manufacture of ornamental articles are *Acervularia davidsoni*, *Phillipsastrea billingsi*, Favosites, different species, and the various massive and cæspitose stromatoporoids. The first is the common "birds eye" of the marble shops. The second, in common parlance, is "cats eye." All the species of Favosites are grouped under the common name of "fish egg," and the massive stromatoporoids furnish the "wavy marble." Specimens for cutting and polishing are not found in pieces of any considerable size.

Flagging Stone.

Flag stone of excellent quality is furnished by the thinner bedded portions of the State Quarry formation. Large amounts have already been used for sidewalks in various parts of the county, and there is an abundant supply for all

future needs. Flag stones of almost any desired dimensions may be obtained. Even when laid in the most trying situations these flags are unaffected by the weather, and under the ordinary tread of foot passengers they last indefinitely.

Limes.

Stone suitable for the manufacture of lime occurs in the county at two horizons. The Le Claire limestone exposed on the Cedar river in section 2 of Cedar township would make a lime equal to the best made anywhere in the world. There is no evidence that it has been utilized in Johnson county, but beds of the same age and of similar quality furnish the limes of deservedly high reputation from Cedar valley, Sugar creek and Port Byron. The white limestone, number 11 of the general section of the Cedar Valley stage, has been burned into lime at a number of points in the northeastern part of the county. One of the most important kilns producing lime from beds of this zone was operated by Mr. Linder in section 34, Tp. 80, N., R. VI, W. Kilns using stone from the same horizon have been worked in sections 8 and 21 of Penn township, near Iowa City in Lucas township, and near the northeast corner of section 22 in Newport township. The local limes, however, have been almost entirely superseded by more desirable magnesian limes made from the Le Claire stage at Cedar valley and Sugar creek in Cedar county.

Sand.

Building sand has been obtained at a number of localities, the most important beds, economically considered, being found in the present flood plain of the Iowa river near Iowa City. There are some fairly good beds of sand in abandoned flood plains, or plains that are now submerged only during the very highest floods, as is illustrated in the southwest quarter of section 22 of Lucas township. There are also sands in the Iowan area southeast of Solon; and along the Iowa river in Oxford and Madison townships there are sand

beds of considerable exent. Very little sand suitable for building purposes is found in the southwestern part of the county.

Clays.

The clays of the county support a number of brick and tile factories. Workable clays are confined chiefly to the loess and alluvium. Clays of good quality are found in the Carboniferous outlier near Iowa City, but the beds are too thin to be worked with profit.

River Junction.—A brickyard owned by J. D. Musser is operated at River Junction. The clay used is a thin layer of alluvium and vegetable mould overlying Kansan drift. Hand moulded, sand-rolled brick are made, dried on the yard, and burned in a common cased kiln. Two kilns, with a capacity of 500,000 each, are burned annually. No machinery is used beyond the ordinary horse-power pug mills.

Oxford.—At Oxford, a brickyard is owned and operated by Mr. John W. Oxer. An alluvial clay or modified loess overlying till of Kansan age, is used. The bed is about twelve feet in thickness with two feet of black loam at the top, beneath which is a band of strong bluish clay, followed in descending order by reddish, highly ferruginous clay which might be used in the manufacture of red pressed brick. A steam plant and Plymouth machine with force feed constitute the principal part of the equipment. The brick are side cut; they are dried in sheds and burned in cased kilns. The machine has a capacity of 30,000 brick per day. In actual practice the daily output when running is from 10,000 to 12,000. To prevent checking the clay has to be mixed with sand.

Tiffin.—Brick and tile are manufactured by the Tiffin Tile Co. An alluvial clay from the flood plain of Clear creek furnishes the raw material. The clay bed is ten to twelve feet thick, and is underlain by sand. It is only recently that the company has undertaken the manufacture of brick. The plant embraces a steam plant of forty-five horse-power, a

Brewer-Tiffany machine, with a capacity of 10,000 three-inch tile daily, steam heated drying sheds, two circular down draft kilns twenty-two feet in diameter, a repress machine, and the necessary trucks, elevators, tramways and chutes for handling the material in the various stages of manufacture. The product embraces six sizes of drain tile, from three to eight inches inclusive, together with side-cut and repressed brick.

Iowa City.—At Iowa City there are two yards that make brick, and one that makes brick and tile. In all cases the clay used comes from the loess. The yard of Mr. Goss is located in the northeastern part of the city. The loess here has a thickness of more than thirty feet, and the part recently worked shows a vertical breast of eighteen feet. The lower part of the exposure is a fine bluish clay, streaked vertically and horizontally with red. The vertical streaks are due to the "pipes" of iron oxide already noted. The lower bluish phase of the loess is very fossiliferous. The upper part of the vertical face is yellow in color, but there are a number of undulating, horizontal ferruginous bands that may represent successive surfaces covered at intervals by wind-driven dust or water-laid silt. The brick are hand made, dried on the yard —each tier, when drying, having separate roof and side curtains for protection from rain—and burned in large clamp kilns.

Mr. C. Gaulocher operates a yard just east of that belonging to Mr. Goss. The clay used is essentially the same, and the process of manufacture is not materially different. No machinery is used beyond the ordinary pug mill. The brick are sand rolled, hand made, and the temporary cased kiln is used for burning. The annual product of the Gaulocher and Goss yards, together, approximates 2,000,000 brick. The brick have a good color and are of excellent quality for ordinary structural purposes.

The third yard is located in the southeastern part of the city and known as the Nicholas Oakes Brick and Tile works. The product of this yard includes ordinary structural brick,

sidewalk brick, repressed brick, and drain tiling ranging from three to eight inches in diameter. Various grades of loess clay are used, and are mixed for the several products in the proportions demonstrated by experience to be best. The bed of clay now used is eighteen feet in thickness. A thirty-horse power steam plant, and a Nolan & Madden auger machine adapted to make both brick and tile, constitute the most important part of the equipment. The machine has a capacity of 12,000 three-inch tile, or 40,000 brick per day. End cut brick are produced. A Perfection repress machine, with a capacity of 5,000 a day, is operated part of the time. The ware is dried in permanent sheds. Two down draft kilns, each twenty-two feet in diameter, are used for burning tile. The brick are burned in a common clamp kiln, the kiln having a capacity of 400,000. Three million brick have been made by this firm in a single year. During the season of 1896 fifteen kilns of tile were burned.

Minerals.

There are a few minerals that occur in the county, but in quantities too small to be of economic importance. There are some thin seams of potter's clay in the Iowa City Carboniferous outlier, and near the home of Mr. Euclid Sanders the same formation contains a thin vein of coal. Coal has also been found either in the drift or immediately beneath it at a number of points in Washington township, and indications of coal are not uncommon in other localities.

Crystals of zinc sulphide (sphalerite) are frequently met with in small cavities or pockets in the Cedar Valley limestones, and good examples of ferrous sulphide (pyrite) is common at the same horizon. These minerals occur here generally in beds containing embedded corals such as Acervularia and massive Favosites. In certain localities these corals have been transformed into hollow geode-like masses as a result of solution, and it is in the cavities so formed that the sphalerite and pyrite are usually found. More frequently, however, the cavities are lined with beautiful crystals of calcite.

Water Supply.

The Iowa and Cedar rivers are the only streams of the county that can be certainly counted as permanent during periods of drought. Portions of the county distant from these streams must depend on wells for a permanent water supply. Fortunately water is abundant in the superficial deposits at depths ranging from fifty to 300 feet. At very few points is any rock drilling necessary to get bounteous supplies of pure, wholesome water.

Water Powers.

The principal water powers in the county are two, one at Coralville and one at the Terrill mill north of Iowa City, both on the Iowa river. At the first the head is twelve feet, at the second it is seven or eight feet. At each there is water enough going to waste to supply additional industries with power.

ACKNOWLEDGMENTS.

The Survey has received valuable information and assistance from Euclid Sanders, Samuel Hess, Gilbert Irish, P. E. Shaver, Bruce Patterson, T. J. Fitzpatrick, G. L. Houser, R. L. McCord, T. H. Macbride, B. Shimek, C. R. Eastman and many others. To each and all of these the writer acknowledges his indebtedness and extends cordial thanks. Professor Macbride has kindly furnished the following notes on the forest trees growing in Johnson county, and Dr. Eastman has contributed the paper on the remarkable fossil fishes of the State Quarry limestone.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FOREST TREES OF JOHNSON COUNTY.

BY T. H. MACBRIDE.

The following is a list of the native larger shrubs and trees growing in Johnson county.

Asimina triloba Dunal. Common Papaw. Found sparingly in the southern part of the county.

Tilia americana L. Basswood. Common.

Xanthoxylum americanum Mill. Northern Prickly ash. Sometimes reaching a height of fifteen feet.

Ptelea trifoliata L. Hop-tree. Not common. In southern part of county.

Euonymus atropurpureus Jacq. Burning bush. Common.

Rhamnus lanceolata Pursh. Buckthorn. Not rare.

Æsculus glabra Willd. Fetid Buckeye. Found only in the southwestern part of the county.

Acer saccharinum Wang. Hard maple, Sugar maple. Not rare. Occurring chiefly on rocky hillsides.

Acer dasycarpum Ehrh. Soft maple. Common along streams.

Acer rubrum L. Red maple. Rare.

Negundo aceroides Moench. Box elder. Common.

Staphylea trifolia L. American Bladder-nut. Rather frequent.

Rhus glabra L. Smooth sumach. Common. Often becoming a small tree.

Robinia pseudacacia L. Common locust, Black locust. Not rare. Frequently cultivated for ornament.

Gymnocladus canadensis Lam. Kentucky Coffee-tree. Rare.

Gleditschia triacanthos L. Honey Locust. Rather common. Often almost destitute of thorns.

Prunus americana Marsh. Wild plum. Very common.

Prunus viginiana L. Choke cherry. Common along rocky hillsides.

Prunus serotina Ehrh. Wild cherry. Frequent. Scattered throughout the forest-area of the county.

Pyrus coronaria L. American crab apple. Everywhere common.

Cratægus coccinea L. Common hawthorn. Common.

Cratægus coccinea L. var. *mollis* Torr. and Gray. Red hawthorn. Common. The comparatively large fruit of this form is edible.

Cratægus tomentosa L. Scarlet thorn. Common.

Cratægus crus-galli L. Cockspur thorn. Not rare.

Amelanchier canadensis Torr. and Gray. Shad-bush, Service-berry, June-berry. Common along rocky slopes.

Cornus asperifolia Mx. Dogwood. Not rare in sandy places.

Cornus stolonifera Mx. Red-osier dogwood. Common along streams.

Cornus paniculata L'Her. Panicled cornel. Very common on high grounds.

Viburnum dentatum L. Arrow-wood. Rather rare.

Viburnum lentago L. Black haw, Sheep-berry. Still quite common along streams.

Viburnum prunifolium L. Black haw. Rare. This and the preceding species were formerly very common, but the clearing of creek and river bottoms for pasture and farm lands has materially affected both species, the latter perhaps suffering more.

Cephalanthus occidentalis L. Button-bush. Common in swampy places.

Fraxinus americana L. White ash. Common. Chiefly along streams.

Fraxinus viridis Mx. f. Green ash. Less frequent than the preceding.

Ulmus fulva Mx. Slippery elm, Red elm. Common.

Ulmus americana L. American elm, White elm. Very common.

Celtis occidentalis L. Hackberry. Very common along the Iowa river.

Morus rubra L. Red mulberry. Not common. More frequently found in the northern part of the county.

Platanus occidentalis L. Sycamore, Buttonwood. Rather common along the Iowa river.

Juglans cinerea L. Butternut, White walnut. Common on hillsides and along streams.

Juglans nigra L. Black walnut. Becoming rather less common. Formerly very abundant along all the streams in the county.

Carya alba Mott. Hickory. Very common, chiefly on higher grounds.

Carya sulcata Nutt. Shell-bark. One tree, probably of this species, is found near Iowa City.

Carya amara Nutt. Bitter-nut, Pignut. Common, chiefly on higher grounds. Specimens of bitter-nuts, resembling *Carya porcina* Nutt. have also been collected, but the occurrence of the species in Johnson county is not established beyond question.

Betula nigra L. River birch, Red birch. Common along the larger streams.

Corylus americana Walt. Hazel-nut. Very common.

Ostrya virginica Wild. Ironwood, Hop horn-beam. Very common, chiefly on higher grounds.

Carpinus caroliniana Wild. Ironwood, American hornbeam. On rocky banks along the smaller streams. Less common than the preceding.

Quercus alba L. White oak. Very common.

Quercus macrocarpa Mx. Bur oak. Very common.

Quercus muhlenbergii Eng. Chestnut oak. Found occasionally on rocky hillsides along the Iowa river.

Quercus rubra L. Red oak. Common on higher grounds.

Quercus coccinea Wang. Scarlet oak. Common chiefly on lower grounds.

Quercus coccinea Wang, var. *tinctoria* Gray. Quercitron, Black oak. Rare.

Quercus palustris Du Roi. Swamp oak, Spanish oak, Pin oak. Occasional along the Iowa river in the northern part of the county.

Quercus imbricaria Mx. Shingle oak, Laurel oak. Found only in the southern part of the county, where it is not rare on the Iowa river and Old Man's creek bottoms.

Salix nigra Marsh. Black willow. Common along the Iowa river and other streams.

Salix amygdaloides Anders. Black willow. Common with the preceding.

Salix discolor Muhl. Glaucous willow, Pussy willow. Quite common on low grounds, chiefly along small streams.

Salix cordata Muhl. Heart-leaved willow. Common on low grounds.

Populus tremuloides Mx. American aspen, Quaking asp. Common generally on low grounds.

Populus grandidentata Mx. Large-toothed aspen, Quaking asp. Poplar. Very common, soon taking possession of neglected clearings on higher grounds.

Populus monilifera Ait. Cottonwood, Necklace poplar. Common on low grounds.

Juniperus virginiana L. Red cedar. Formerly common on rocky bluffs along the Iowa river. Now quite rare.

The nomenclature in the above list is that of the sixth edition of Gray's Manual.

ON THE OCCURRENCE OF FOSSIL FISHES IN THE DEVONIAN OF IOWA.

BY DR. C. R. EASTMAN.

The fish faunas of the Devonian and Carboniferous systems present such marked differences as in a measure to justify the assertion that a great revolution in ichthyic development took place toward the close of the former period. During the Devonian, the fishes commonly known as Placoderms greatly preponderated over the Elasmobranchs, which continued to hold a subordinate position, both relatively and

absolutely, from the date of their initiation onward. But with the extinction of the Placoderms at the close of the Devonian, the Elasmobranchs entered upon a new era of development, increasing prodigiously in point of numbers and variety, attaining greater size, and becoming more formidably armed. In contrast with the remarkable dearth of Elasmobranchs in the Silurian and Devonian, upwards of 600 species have been described from the Carboniferous of this country and Europe; and it is probable that this group of fishes was much more abundant during the Carboniferous than at present or during any other geologic period.*

With the exception of *Cladodus* and its allies, very few representatives of Carboniferous genera have been met with in the Devonian, and these are restricted chiefly to the upper members of the system. Again, while the earliest and most primitive type of Elasmobranch dentition with which we are acquainted (*Protodus*, *Diplodus*, *Cladodus*) was adapted for piercing, and while this type prevails to the exclusion of almost all others in the Devonian, at least three-fourths of the known Carboniferous species possessed crushing teeth, which were "adapted to the trituration of mollusks and crustaceans; and the number of those provided with cutting or piercing teeth was comparatively small." † All of these crushing teeth are more or less highly specialized, yet they appear suddenly and in great profusion in the lowermost Carboniferous, apparently unlinked to any forms that have gone before. Thus the large group of the *Cochliodontidæ* is commonly supposed ‡ to be confined to the Carboniferous; and the same may be said of the *Psammodontidæ*, if we except a very doubtful species founded on imperfect material from the Corniferous limestone (*Psammodus antiquus* Newb.).§

* "The defensive spines found in the Carboniferous rocks outnumber ten to one those of all other geological systems, and they surpass in very much greater proportion anything we find in the living fauna."—*Newberry, J. S.*, Paleozoic Fishes of North America (Monograph XVI of the U. S Geol. Survey, p. 79) 1889.

† *Op. cit.*, p. 184.

‡ If we can regard the genus as correctly determined, a fragment of *Cochliodus* has been found in the Upper Devonian of Belgium. *Cf. Dormal, V.*, Sur les poissons dévoniens dans le bassin de Namur (Proc. verb. Soc. Malacol. Belg., vol XVI, p. cxxxv). 1887.

§ The only account of this species is that given by Newberry in the Bulletin of the National Institute for 1857, copies of which are now very scarce. The author was careful to state that no perfect specimens had been secured, and it was conceded as "possible that they are generically different from *Psammodus*." It is not known whether the originals of this description are still in existence; a search for them at the School of Mines Cabinet of Columbia University proved unsuccessful, and the form has not been recognized in other collections.

These families comprise the bulk of Carboniferous Selachian teeth; but although certain generic relationships are observable among their respective members, we know as yet nothing of intermediate forms connecting the two families, nor of the manner in which compound teeth originated from marginal. That the separation of Psammodont and Cochliodont forerunners took place during the Devonian can hardly be doubted; but how the teeth were arranged in the ancestral condition, and first became fused together, we have had as yet no means for determining.

The Dipnoans likewise possess compound teeth which are curiously modified; but here again we must confess ignorance of the stages of specialization passed through by them. It is conceded that this group of fishes was derived from the Elasmobranch stem; nevertheless we cannot say definitely when the Dipnoan branch was given off, although it was probably subsequent to the development of compound teeth in the parent stock. If by any chance the primitive stages of Dipnoan and Elasmobranch compound dentition should become known to us, and should prove to be in essential agreement, it could not be doubted that the former are directly inherited from the latter. Let it be proved that the compound teeth of Dipnoans and Elasmobranchs have arisen through *convergence* instead of parallelism, and we can state positively that the divergence of these groups took place not earlier than the Devonian. Fortunately, additional evidence is now at hand, which affords some insight into these problems, and reveals closer affinities between Dipnoan and Elasmobranch dentition than have been known to exist before. Among other things it acquaints us with types of compound teeth, such as existed in primitive Dipnoans; and the analogy with primitive Selachian teeth is such as to leave no doubt that they had a common origin, for which no earlier date than the Devonian can be assigned. Evidence of this character, it is needless to remark, is of far greater importance than the discovery of merely new genera and species, no matter how much intrinsic interest the same may possess.

The evidence in question consists of large numbers of perfectly preserved fish-teeth, forming part of a remarkable fauna recently discovered by Professor Calvin in rocks which he considers to be of Upper Devonian age. Some of the teeth bear such close resemblance to those of Carboniferous sharks that they were at first mistaken for them or their allies; but with the acquisition of larger material very remarkable transitions were observed between them and undoubted Dipterid species (*cf.* Plate iv, Figs. 32–42). Among other features, a true root was found to be absent, as in the Dipterids; and when finally the microscopic structure was compared with that of a number of Dipnoan genera, no essential differences could be detected. As in *Dipterus*, *Ctenodus*, *Ceratodus*, etc., the dental plates are composed of an osseous tissue instead of dentine; the vascular canals, which are of nearly uniform size, form an irregular network, and give off numerous exceedingly minute canaliculi; moreover, small lacunæ, very distinct from the vascular canals, are interspersed here and there in the ground substance. All this is very different from the structure of dentine, in which lacunæ are absent, and there is either a pulp-cavity or a system of medullary canals corresponding to it. In a word, we have here a variety of new Dipnoan forms, differing widely from those that have been hitherto described, and remarkable in many respects. Owing to the absence of other parts of the skeleton nothing can be stated at present in regard to their family position.

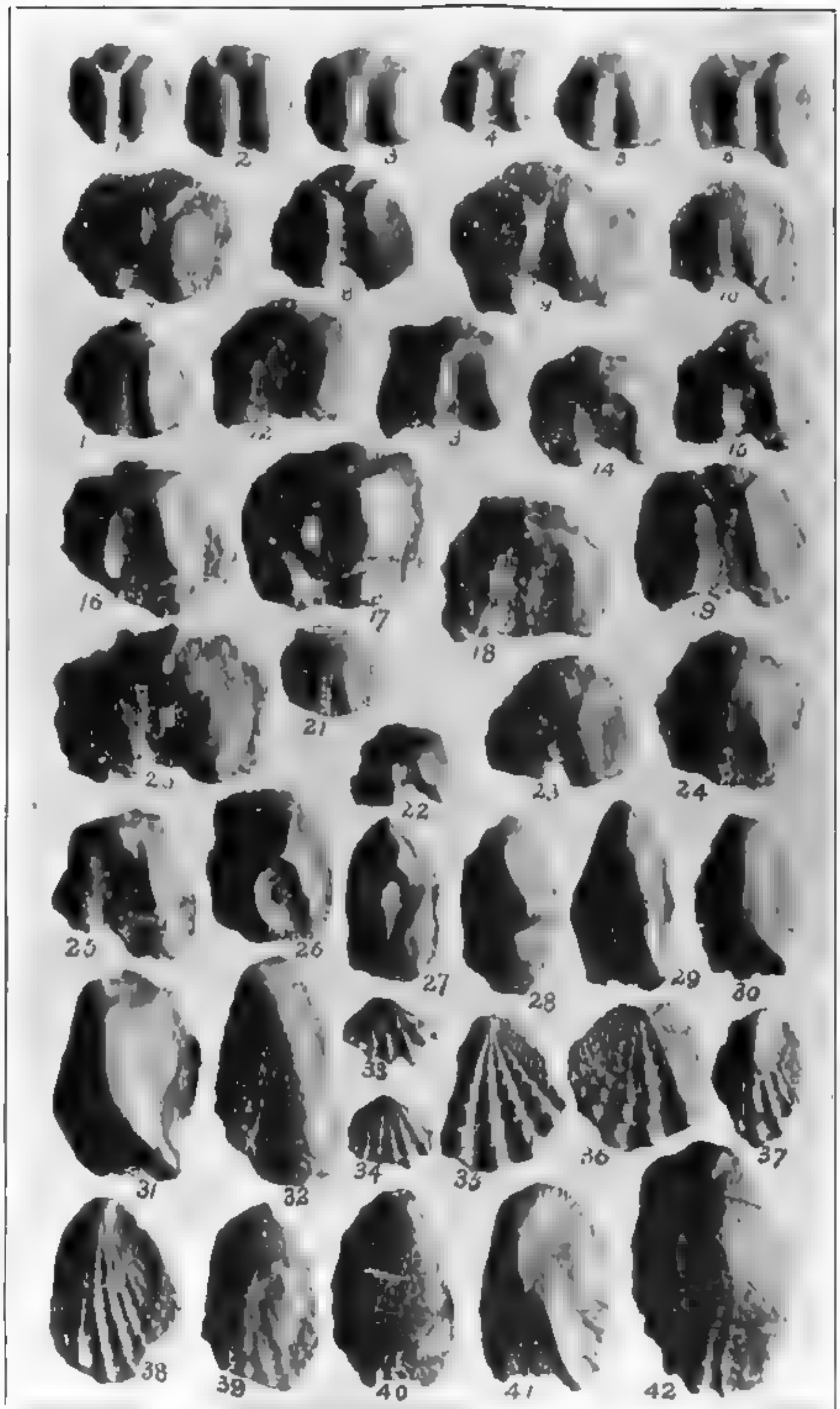
Although it is beyond the scope of the present article to enter into any descriptions of these remains, still a few words may be said concerning the series of variations exhibited by the form which we will designate provisionally as *Synthetodus*.* Some of these variations obviously represent different stages of growth; others, which are capable of being co-ordinated with one another, enable us to distinguish between upper and lower dental plates; and still others, which are of more trenchant character, may be regarded as having specific value.

* Σύνθετος, put or welded together; ὀδοὺς, tooth.

Several examples of a species for which the name *S. trisulcatus* is suggested by Professor Calvin, are shown in the two uppermost rows of Plate iv. This may be regarded as the most primitive type of Dipnoan dentition that has yet been discovered. A comparison of a number of examples proves that the form shown in Fig. 1 represents a young, or at least, an immature stage, having the sutures between its constituent elements more or less open. The next stage (Figs. 4, 8) is marked by a gradual coalescence of the lateral and symphysial elements, together with a filling in of the median area, so that this last appears nearly flat on the oral surface.

A parallel to the condition just described is furnished by several species of *Copodus* among the sharks, although here all traces of a median longitudinal suture have disappeared. The upturned lateral margins of *C. spatulatus* and *C. prototypus* are clearly homologous with the two lateral elements of *Synthetodus*. That the dental plates of *Synthetodus* were supported by cartilage, as in the sharks, instead of by bone, appears probable from the occurrence of a distinct plate lying directly across the symphysis, as well as from the nature of the base. Considering the wonderful preservation of these teeth, we should expect to find some of them still attached to the palato-pterygoid and splenial bones, providing the cranium was ossified. As no traces whatsoever of bone have been found, and as the dentition is comparable with that in *Copodus* (*cf.* Fig. 25) and other genera of sharks, the conclusion appears irresistible that we have here evidence of lowly forms of Dipnoans, whose dental plates recall the ancestral conditions of pavement teeth such as was developed by Elasmobranchs prior to the divergence of lung-fishes.

The adult stages of *S. trisulcatus* are not shown in any of the photographed specimens, but in Plate iv, Figs. 14–16 may be seen mature individuals of another species of *Synthetodus*. Evidences of wear are very palpable at this stage, and hollows are excavated in the central portion conformable to the opposing dentition (Figs. 18, 19). Long continued



TEETH OF DEVONIAN LUNG-FISHES. FROM THE STATE QUARRY FISH BED, JOHNSON COUNTY, IOWA.

abrasion gives rise to smooth, elliptical or tongue-shaped depressions, precisely similar to the worn surfaces in the teeth of *Copodus*. Finally, in old age, when detrition of the surface is no longer compensated for by growth of the tooth from its base, the oral surface is worn nearly flat, and the margins become greatly attenuated. Several examples have been observed exhibiting this stage. Figures 12 and 21 show it approximately.

Synthetodus and its allies or derivatives make up the greater part of the Dipnoan remains from this horizon. A few teeth have been noticed which bear some resemblance to those called *Conchodus* by M'Coy, and *Cheirodus* by Pander;* and these are seen to pass by gradual transitions (Figs. 38–42) into true Dipterid forms. The genus *Dipterus* is represented in this country by two species from the Catskill and four from the Chemung group of Pennsylvania;† but the forms discovered by Professor Calvin in the old State Quarry beds, near North Liberty (Figs. 33–38), are not identifiable with any of these. It is possible, of course, on the theory of the shagreen origin of dental plates to explain Figures 39–42 as representing obsolescence instead of initiation of radial ribbing. But as the ground-type, *Synthetodus*, borne possibly by a cartilaginous lung-fish, is seen to have been smooth; and since, furthermore, a passage is observable between plications (Fig. 19) and ribs (Fig. 41), as well as between smooth ribs and denticulated (Figs. 33–35); it appears preferable, at least in the opinion of the present writer, to regard the dental plates of *Dipterus valenciennesi*, *Ctenodus cristatus*, etc., as extreme modifications of a type that was first entirely smooth, and next became smooth-ribbed. The crenulation of the margin in

*Pander's work on "Die ctenodipterinen des devonischen systems" has remained as yet inaccessible to the present writer, and he is indebted to Mr. A. S. Woodward, to whom photographs were submitted, for having suggested a similarity to some of the Russian forms.

†An unfinished manuscript lately discovered among the effects of Professor Newberry, and to be issued as a posthumous publication under the editorship of Mr. Bashford Dean, contains descriptions of two new species of *Dipterus* from the Chemung group of Pennsylvania. Mr. Dean was kind enough to compare the originals with photographs of the new Iowa species, and pronounces them distinct. The same MS. also mentions the occurrence of *Ptyctodus* teeth in the so-called "Kinderhook beds" of Louisiana, Missouri; and it is stated that no differences can be detected between them and the well-known *P. calceolus*, which is limited to rocks of Devonian age. This is important, for it furnishes additional confirmation of the view contended for by Calvin and Keyes that a part of the formation at Louisiana is unquestionably Devonian.

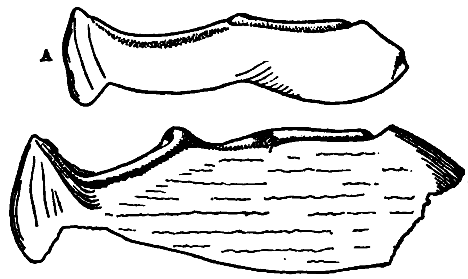
Psephodus does not indicate the decadence of ribbing, but a primary stage of its introduction.

Indications of Arthrodires occur in the form of large, heavy fragments, some of which must have pertained to fishes of considerable size. Most of the remains that have been examined thus far are too imperfectly preserved for satisfactory determination, but one or two are plainly referable to the genus *Dinichthys*. One fragment shows the base of the supraoccipital region of the cranium, indicating a creature of about the size of *D. intermedius*. Another shows the articulating condyle of an antero-dorso-lateral plate. As this genus is already known from the Devonian of Manitoba, and from the Hydraulic limestone (Hamilton) of Wisconsin, its occurrence in the North Liberty beds is not surprising. It is to be hoped that further search may be rewarded by the discovery of more numerous and perfect specimens than have yet been secured.

Turning our attention lastly to the Elasmobranchs, we find that Cladodonts and other types of piercing and cutting teeth are conspicuously absent; neither have any crushing teeth been encountered that can be positively identified as Selachian, although in the case of some forms it will require careful microscopic study to determine their nature absolutely. It is also noteworthy that no dermal spines have been met with; hence, as far as present evidence goes, there is nothing to disprove the generalization that defensive armament was uncommon among pre-Carboniferous sharks.

The absence or paucity of Selachian remains in these beds is compensated for by prodigious numbers of Chimæroids. So far as observed, they all pertain to a single species of *Ptyctodus* (*P. calceolus*), and as a rule, only the detached and partly abraded tritoral areas are preserved. Nevertheless these fragments are so plentiful that the rock may be said to be fairly charged with them in places. The average size of the tritors appears to be somewhat smaller than in *P. calceolus*, but where the complete jaw or dental plate has been observed, it presents no characters which serve to distinguish it from

that species. The accompanying text-figures are instructive inasmuch as they show for the first time the nature of the symphysial region in the American and also a European species. The inner face of the dental plates (both of the figures show the outer face) retains markings at the symphsis where they were suturally united with their fellows. These dental plates possessed but one tritor each, in advance of which was a cutting edge terminated in front by a sharp projection. The original of figure B is the most perfect of several examples preserved in the Museum of Comparative Zoology at Cambridge, all from the Middle Devonian of the Eifel district, in Rhenish Prussia. For this form the name *P. molaris* is proposed. Other species with two tritors to each dental platè, have been described from the Middle Devonian of Russia and the Baltic Sea Provinces. The solitary American species has, so far, been reported from the Middle Devonian (Hamilton) of Canada, and from a few localities in Iowa, Illinois, and Missouri.



A

B

FIG. 10. Dental plates of Ptyctodus, showing outer surface. A *Ptyctodus calceolus* N. and W. (from Iowa); B *Ptyctodus molaris* Eastman (from Europe).

From the foregoing it will be apparent that we have here to deal with a unique and highly interesting assemblage of fossil fishes. A number of new Dipnoan genera are encountered, some of which present astonishing resemblance to primeval sharks, and others are connected by gradual transitions with *Dipterus*. Careful study of these forms can hardly fail to clear up many difficult problems affecting Paleozoic fishes. The presence of *Dipterus* and Arthrodires brings the Iowa fauna into relationships with the Chemung and Catskill of Pennsylvania on the one hand, and with the Waverly of Ohio on the other. Nevertheless the different aspects of these faunas when compared with one another are very

considerable. Through *P*[illegible] the fauna is related also to the Hamilton of the Mississippi valley. The abundance of this form, and the absence of all other Elasmobranchs is a surprising circumstance. However, it is more than likely that further search will bring to light many forms which we should naturally expect to find in rocks of this horizon.

These, in brief, appear to be the leading conclusions arrived at from a somewhat superficial examination of the material that has been thus far collected. The results of a more detailed investigation will form the basis of a future report.

An idea of the perfect preservation of these fish remains may be had from an inspection of the accompanying plate, reproduced from a photograph. On this it is only possible to show a few of the more interesting forms.

GEOLOGY OF CERRO GORDO COUNTY

BY

SAMUEL CALVIN.

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CONTENTS.

INTRODUCTION.

SITUATION AND AREA.

From an agricultural point of view Cerro Gordo county embraces one of the most beautiful tracts of land in Iowa. The region indeed is not without the charm of beauty from any point of view. This county lies well toward the west line of the northeastern quarter of the state. It is only seventeen or eighteen miles from the Minnesota boundary. Worth county, on the north, separates it from Minnesota. It has Hancock county on the west, Franklin on the south, and Floyd on the east. It is approximately square, embracing the usual sixteen congressional townships. Outside of Mason City each congressional township is now organized into a civil township.

PREVIOUS GEOLOGICAL WORK.

Cerro Gordo county has received but little attention in previous official surveys. It was not included in the area directly investigated by Owen, nor does the report of Prof. James Hall refer to it in any way. The survey conducted by Dr. Charles A. White covered some of the more prominent characteristics of the region, and his report* devotes a few pages to the description of Cerro Gordo and Worth counties considered as a single area. There are also, in the same report, some references to the peat of Cerro Gordo county in the chapter on Economic Geology, and to certain topographic phenomena around Clear Lake, under the head of Physical Geography. In 1872 there was published, as advance sheets of the Twenty-third Annual Report on the State Cabinet of New York, a paper by Hall and Whitfield, in which some fossils from the shales at Hackberry Grove are described and the geological age of the formation is discussed.

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TOPOGRAPHY.

The topography of the greater part of Cerro Gordo county might be regarded by some observers as somewhat characterless and monotonous. Leaving out the western tier of townships the remaining portion of the county is a gently undulating drift plain, almost level over large areas. Stream valleys that have cut to but a very limited extent below the general level, and a few knobs or ridges that rise to a height of twenty to thirty feet above the otherwise unbroken plain, give some diversity to a landscape in general devoid of salient topographic features. The drift covering the county is in some places very thin; erosion since the deposition of the drift has been insignificant in amount, and hence the most conspicuous hills and valleys of eastern Cerro Gordo are in reality remnants of a preglacial topography.

All the eastern part of the county is occupied by Iowan drift; the western tier of townships is almost wholly occupied by the knobs, ridges and kettle holes that characterize the marginal moraine of the Wisconsin drift, the Altamont moraine of Chamberlin. A small area in the southwest corner of Grimes township presents some of the characteristics of plains of Wisconsin drift; but this last area is so small as to make it comparatively unimportant. The county is, therefore,

* Rept. Tenth Census, vol. X, pp., 261-263.
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AREA OF IOWAN DRIFT.

The Iowan drift area, which occupies about three-fourths of the surface of the county is, as already stated, a plain, only slightly modified by surface irregularities. The most marked topographic features of this area are associated with the valley of Lime creek. From the point at which the stream enters the area of Iowan drift, near the northwest corner of Lincoln township, until it leaves the county near the southeast corner of Portland, Lime creek flows in a wide and ancient valley that has been only partly filled with debris by the several glaciers that have successively occupied the region. The valley varies in width from one-fourth of a mile to more than three miles. In depth it ranges from from twenty to seventy feet. The channel that has been cut since the deposition of the Iowan drift is a shallow trough wide enough to accommodate the stream in ordinary stages of water. There is, strictly speaking, no flood plain, at least there are no alluvial deposits; but a plain covered with Iowan drift and strewn with conspicuous Iowan bowlders, usually begins at the margin of the shallow channel. and is doubtless partly overflowed at high water. In the western part of Lime creek township the stream flows nearly east from the west line of the township to near the center of section 27. In this part of its course the valley is bounded on the south side by a steep escarpment, twenty to thirty feet in height, in places rocky, in other places seemingly made up of drift. The stream flows close to the foot of the escarpment. A low drift covered plain begins near the level of the water on the north side of the channel and extends back from one-eighth to more than one-half mile. The plain rises gradually to the north and is bounded in this direction by a more or less defined terrace eight or ten feet in height. From the margin of the terrace a second plain, which, like the first, is gently inclined toward the stream, reaches north-

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FIG. 11. Abandoned channel of Lime creek north of Mason City. This is an interglacial channel, apparently excavated and occupied by the stream during the interval between the Kansan and Iowan stages of the Pleistocene. This interval includes three distinct episodes, namely: the Buchanan interglacial stage, the stage of the invasion of southeastern Iowa by the Illinois ice sheet, and the interglacial stage (unnamed) following the retreat of the Illinois ice.

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ward with a maximum width of two or three miles, and terminates in low, imperfectly defined hills. These low hills mark the margin of the old preglacial valley, and beyond them stretches away the unbroken drift plain.

Southeast of Mason City the creek flows near the middle of its old valley, and the escarpment forming the eastern boundary cuts obliquely the west line of section 7 of Portland township. The height of the escarpment above the second bench of the river valley is, at this point, thirty-five feet. The boundary of the valley is similarly marked on the west side at a distance of a mile, or a mile and a half from the stream.

In the southern part of Portland township, the Lime creek valley trends nearly east. Here again the stream flows near the southern margin of the valley. For some distance it follows the foot of an escarpment made up of Lime creek shales and presenting a front seventy feet in height. From the summit of this escarpment the normal drift plain stretches away with gentle undulations to the south. On the north side of the stream the bowlder strewn plain begins near the level of the water and rises very gradually toward the north until, at a distance of two or three miles, without marked break or change of slope, it blends into the plain of drift which lies at the general level of all the eastern part of the county. In the immediate neighborhood of the stream, however, there is the unusual spectacle of two drift plains of the same age, sharply offset one from the other by a vertical rise of seventy feet. The interesting relations of these two plains are due to topographic features imposed upon the region before the oncoming of the earliest glacial period. The offset between the two plains is most marked where the stream flows close to the foot of the escarpment in sections 34 and 35, but it is continued westward through sections 33 and 32, receding farther and farther from the stream, and is finally lost in the general level of the county at the western limit of the preglacial valley.

The valley of Lime creek abounds in interesting features throughout its whole course in the county. In the Iowan drift area it had been excavated to a great width in preglacial time and probably accommodated one of the master streams of ancient Iowa. The valley was partly filled with Kansan, and probably with an earlier drift, but during the interval following the Kansan ice invasion, it was in part re-excavated,—the terrace already noted in Lime creek township, and similar terraces at other points along the valley, indicating the width attained at the time the interval was brought to a close by the invasion of Iowan ice. This later ice distributed only a thin mantle of drift which failed to disguise the pre-existing topography. A thin sheet of till, with numerous and large bowlders was spread over the higher plain, over the terrace, or second bench, and over the low plain

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sents the amount of erosion since the close of the Iowan glacial period.

An abandoned channel of Lime creek, with well defined rocky bluffs that are in places forty feet in height, (Fig. 11) is an interesting topographic feature in sections 27, 34 and 35 of Lime creek township, and section 2 of Mason City. At the elbow of the stream east of the center of section 27 in the first named township, the present channel bends toward the southwest, while the abandoned channel trends almost directly south. The southerly course is maintained for a little more than a mile, when the channel bears southeast and crosses the south line of the township from sixty to eighty rods east of the southwest corner of section 35. In section 2 of Mason City township it maintains its southeasterly direction, but in the northeast quarter of this section it enters an expansion of the old preglacial valley and loses its character as a definitely bordered channel. The course of the stream that excavated this old channel continued southeastward beyond the middle of section 1, and then turned southward to join the present channel near the south line of section 12, Mason City township. The part of the channel of greatest interest is that in sections 27, 34 and 35 of Lime creek, and the northwest quarter of section 2 of Mason City. It is in this part of its course that it is defined by rocky bluffs. Here it is also narrow, scarcely exceeding 100 yards in width. Topographically the channel is young. It was occupied for only a very short time as compared with the geologic ages required to excavate the broad valley which the stream generally follows in the Iowan drift area in other parts of the county. As to the age of the narrow rock-walled portion of the channel there is evidence that the excavation was completed before the invasion of Iowan ice, for Iowan drift and numerous typical Iowan bowlders lie apparently undisturbed throughout the greater part of its course. The present stream seems to follow the preglacial valley, so that it is scarcely possible that this channel was cut and afterward abandoned in preglacial times. The

most probable succession of events would be, (1) a preglacial valley occupied by an important stream was cut to a width of from two to three miles. In places the width may have exceeded the maximum given; in others the real width may have been less than the minimum. One of the narrower parts of the old valley was just below the point at which the abandoned channel diverges from the present one. (2) The narrow part of the preglacial valley was choked with dirt during the advance and retreat of the Kansan ice. (3) After the disappearance of the Kansan ice the drainage in general followed the old valley, but owing to obstructions, probably not far below the point at which the divergence occurred, the stream was turned aside and compelled for a short distance to make a new channel in which it continued to flow during the interval between the Kansan and Iowan drift periods. The channel cut during this interval is in reality only about two miles in length. In the remaining portion of its course until it joined the present channel, the stream followed the eastern portion of the preglacial valley. (4) During the Iowan glacial period two things probably occurred. The obstruction of Kansan drift may have been in part plowed away, and the channel followed by the stream during the interglacial period may have been in part filled with Iowan drift. That the now abandoned channel was so filled in part is attested by observed facts; and whether the obstruction in the preglacial valley was plowed out or not, the stream, after the retreat of the Iowan ice, left the channel it had made in interglacial time, and once more followed the older valley. On this hypothesis the abandoned channel represents the amount of rock cutting accomplished in the interval between the Kansan and Iowan glacial stages. Compared with the amount of erosion since the close of the Iowan stage it is many times as great. It may safely be asserted that the interglacial period in question was relatively long. A comparison of Figures 11 and 12 may afford some measure of the relative length of the two intervals. Figure 11, however,

shows only a part of the rock cutting accomplished in the period between the Kansan and Iowan stages, for the abandoned valley is now filled to a depth of several feet with drift and peaty humus, while Figure 12 shows the entire amount of valley-making accomplished by the Shell Rock river at the point chosen for illustration, in all post-Iowan time.

The northeastern corner of the county is traversed by the valley of Shell Rock river, a valley very different so far as relates to its history and topographic characteristics from that of Lime creek. Shell Rock valley is new. It traverses the higher drift plateau. Its depth as a rule is only a few feet below the general drift plain and its width is just suffi-

FIG. 12. View on the Shell Rock, showing the very shallow, trough-like channel cut in the Iowan drift and underlying limestones. The contiguous fields are cultivated practically to the water's edge. Northwest quarter of section 27. Falls township.

cient to accommodate the present stream. In many places the drift plain, with its houses, barns and cultivated fields, begins at the margin of the shallow, trough-like channel and spreads away without perceptible slope, to the horizon (Fig. 12). In other places the stream has cut through low ridges of rock and developed miniature bluffs that persist for a short distance and then fade into the low grassy slopes that come down

FIG. 13. View of the low rocky bluff on Shell Rock river, in northwest quarter of section 28. Falls township.

to the water's edge (Fig. 13). Below Plymouth for a few miles the channel is cut continuously in rocky strata to a depth of eight or ten feet. At a few points, as at Vermilya's bluff in Sw. qr., Ne. ¼, Sec. 35, Falls township, the rocky walls on one or the other side of the valley attain a height of thirty or

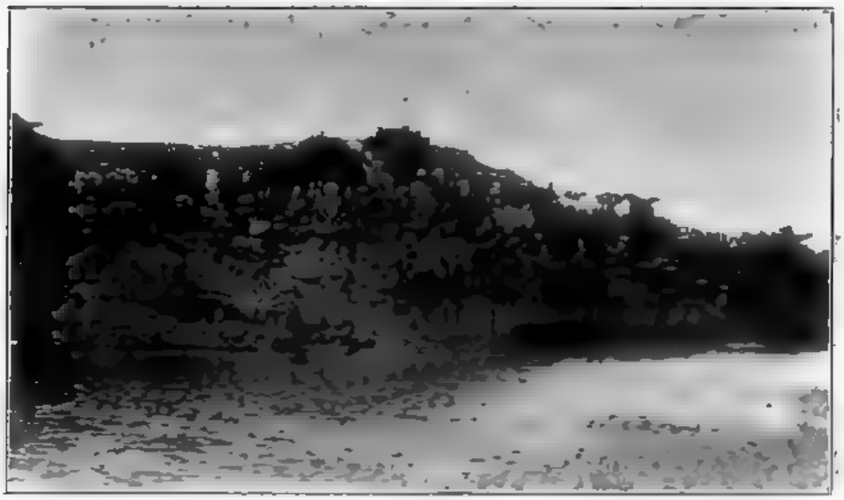


FIG. 14. Vermilya's bluff, the highest rocky escarpment on the Shell Rock river, in Cerro Gordo county. Northeast quarter of section 35. Falls township.

forty feet (Fig. 14), but in such cases the bolder topography is due to conditions developed in preglacial time. In general the valley of the Shell Rock in Cerro Gordo county is narrow and shallow, and represents work accomplished by the stream since the retreat of the Iowan ice.

In the vicinity of Mason City the valley of Willow creek shows the same characteristics as the valley of Lime creek. It has a depth of fifty feet measured from the level of the water in the stream to the summit of the hill west of the C., M. & St. P. depot. A short distance west of the depot the

FIG 15. Iowa bowlder in Mason City, on low plain within the walls of the preglacial valley of Willow creek.

railway cuts through fossiliferous beds of the Lime creek shales, but the bottom land between the railway and the stream, averaging half a mile in width, is covered with drift to a depth in places of fifteen or twenty feet. A valley more than fifty feet in depth, and fully a mile in width was excavated here before any drift was deposited. Iowan bowlders, some of them of great size (Fig. 15), lie scattered over the low plain within the walls of the valley as over the corresponding plain along Lime creek. Here as in many other parts of the county

the successive drift mantles were in the aggregate too thin to completely obliterate the preglacial topography. The valley was never more than partially filled with drift, and beyond the limits of the valley, on the plain south of the railroad, the plain in which the valley was cut, the drift mantle is so thin that Lime creek shales of Devonian age are exposed by the plow.

Preglacial hills and ridges stand out to a limited height above the general surface in sections 16 and 17 of Lake township. In the northeast quarter of 17 there is a low ridge, half a mile in length, trending northwest-southeast, and composed of Lime creek shales with scarcely any covering of drift. This ridge lies between the forks of Willow creek. Its structure, and its relations to the drift lying in the adjacent valleys and lapping up on its sides, indicate that it belongs to a system of topography developed before the earliest glacial period. A similar ridge, with drift bowlders sprinkled over its surface, but with a soil made up of decomposed Devonian shales, extends through the northern part of section 16.

A ridge, conspicuous for this region, passes from section 24 of Mason township into section 19 of Portland. It rises sixty feet above the valley of Lime creek, and twenty feet above the drift plain to which the road descends from its summit toward the south. Near the summit the rain-wash in the sides of the road expose undisturbed shales of the Lime creek stage. A thin sheet of till extends over the ridge, and heavier bodies lie on the lower grounds on either side; but the body of the ridge itself, as an eminence overlooking low lands on the north and south, is older than the oldest drift.

The scantiness of the drift materials in certain localities, and the fact that the present hills and valleys are, to a large extent, remnants of a preglacial topography, are well illustrated at numerous other points within the county. For example, there are many bowlders lying over the plain that begins at the summit of the seventy-foot escarpment in section

35 of Portland township, but in cultivating the fields the farmer drives his plow through Devonian shales. The same shales are cut through by the roadway at the summit of a long hill near the southeast corner of section 24 in Owen township, while undisturbed drift lies deeply over the adjacent valleys. Along the road leading from Mason City to Clear Lake, almost every excavation, whether made in hill or valley, cuts through the thin layer of drift and reveals the yellow shales, which here constitute the country rock. In the southwest corner of Portland township there are numerous exposures illustrating the same relations. The valleys contain undisturbed drift and the hills are made up of undisturbed country rock.

Over large areas in the eastern part of Cerro Gordo county the drift is, after all, comparatively deep, and outside of such phenomena as have been discussed above, this area may be looked upon as a drift-plain with gentle undulations that are not always erosional in origin. A typical portion of this plain begins at the eastern or northeastern margin of the old Lime creek valley and occupies nearly all of Falls township, together with adjacent parts of Lime Creek and Portland. The same plain, broken only by the post-glacial erosion of a few small streams, covers nearly the whole of the area east of the Altamont moraine and south of the valleys of Willow creek and Lime creek. Throughout a belt several miles in width, and lying on both sides of the northern boundary of Dougherty, Geneseo and Pleasant Valley townships, the plain is typically developed. Its western limit coincides very nearly with the east line of Grimes and Union. An area of similar topography lies between Lime creek and Willow creek in southwestern Lincoln and the northern part of Lake.

ALTAMONT MORAINE.

The area of the Altamont moraine is one of unique topography. Geographically it corresponds very nearly with the western tier of townships so far as it is included in Cerro

Gordo county. In the southwest it extends a short distance east of the limit of these, and occupies a few square miles in the western edge of Mount Vernon and Pleasant Valley townships. The surface of the area is quite irregular, and presents a series of knob-like hills and undrained marshes arranged in the most lawless manner. Erosion has played a very unimportant part in producing the present surface configuration of this morainic belt.

One of the most broken and hilly portions of the moraine in Cerro Gordo county occurs in the northwest corner of Grant township. The hills are simply knobs of drift that were irregularly heaped up along the margin of the Wisconsin ice. Their height above the tortuous, marshy valleys that wind in and out and branch and rebranch without definable system, so

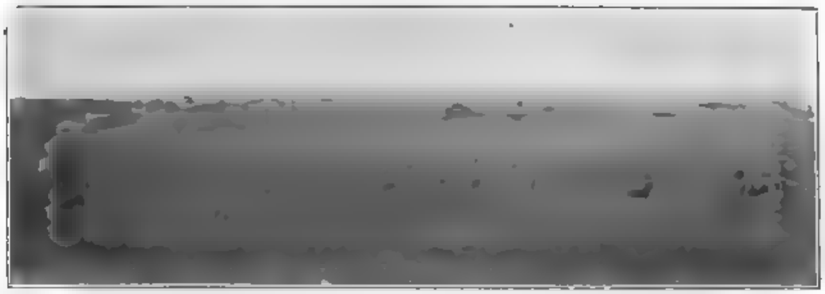


FIG. 18. The Altamont moraine in section 1 of Grant township

as practically to surround each individual knob, varies from forty to seventy or eighty feet. The slopes are often steep. The traveler following the wagon roads must be content to make slow progress, and must often make long detours to avoid impassable marshes or impracticable hills.

Southeast of Lime creek in Grant township, the irregularities of the surface are less pronounced. The relief is less, the curves are not so sharp, and yet the topography is in marked contrast with the gently undulating plain of Iowan drift that begins not far to the east. The milder features of the knobby moraine are continued southward to Clear Lake,

and for a few miles south of that body of water the gentler curves that begin south of Lime creek characterize the topographic forms. Section 3 of Grimes township, is the center of an area of considerable extent, in which moranic topography is typically developed (Fig. 16), the moraine here having a width of six or seven miles. In the southern part of Grimes township the knob-like hills are replaced by comparatively gentle undulations.

Kettle holes are very characteristic features of the area occupied by the moraine. These are saucer-shaped ponds or marshes that, in the majority of cases, are only a few rods in diameter. They are abruptly depressed below the surrounding level, but they may be found in all situations from the low, ill-drained ground between the hills, to the top of the highest eminences. In seasons of ordinary rainfall they are filled with water and may support a dense growth of rushes, wild rice, and less conspicuous aquatic plants. Evidently these peculiar ponds were formerly more numerous than at present, for in many instances peat bogs have taken the place of kettle holes, the depressions having been gradually filled with partially decayed vegetation. All these ponds, indeed, are in process of filling; and the cultivation of the hills, which is every year becoming more general, will hereafter result in the mingling of considerable quantities of earthy matter with the peaty deposit.

The basin of Clear Lake is simply a large depression in the Altamont moraine, and it may be regarded as genetically related to the kettle holes already described. The maximum depth of the water in the lake is about fifteen feet. Except at the outlet, at the east end of the lake, the basin is surrounded by low knobs and hills of drift.

Lake basins of smaller size than Clear Lake, now generally filled with peat and supporting annually a heavy crop of coarse slough grass, are found at various points within the limits of the moraine. A typical extinct lake bed of the kind described is seen in sections 24 of Union township and 19 of Mount Vernon.

At various points along the east end of Clear Lake, as, for example, between the lake and the Assembly grounds, there is a rather low but conspicuous ridge of sand and gravel that is more recent in age than the moraine. This ridge has had the same origin as the "walls" and causeways that commonly occur on the low or swampy sides of northern lakes, and has been produced by the heaving and expansion of the ice during the successive winters that have come and gone since the lake came into existence. The expanding ice is crowded shoreward along that margin of the lake that offers least resistance, and carries with it the clay, sand, gravel, bowl-

FIG. 17. Effect of expansion of ice in Clear Lake. Along the low, gently sloping margins of the lake the ice is heaved and broken and shoved shoreward with tremendous energy, carrying with it great quantities of sand, clay, bowlders and other included materials.

ders or other substances that may be frozen in its lower surface, or are so situated as to be moved by the great mechanical energy exerted in connection with the process of expansion (Fig. 17).

In the western and southwestern part of Grimes township the moranic topography gradually disappears, and the softened curves blend eventually into the level plain characteristic of the area covered with Wisconsin drift.

ELEVATIONS.

The following table, taken from Gannett's Dictionary of Elevations, shows the relative altitudes of a few of the more important points in the county. It will be observed that the greatest elevations occur at Clear Lake and Ventura, in the Altamont moraine.

Mason City—	
C., M. & St. P. depot	1,128
Iowa Central depot	1,130
Clear Lake	1,238
Plymouth	1,125
Portland	1,071
Ventura	1,252

DRAINAGE.

With respect to drainage, as in the case of topography, Cerro Gordo county is divisible into two areas. The portion of the county occupied by Iowan drift has relatively perfect drainage, and the stream channels are fairly well defined. With the exception of that part of the channel of Lime creek which passes through the northwest corner of Grant township, it can scarcely be said that there is a well defined water course in the area of the Altamont moraine.

Lime creek.—Lime creek drains the larger part of Cerro Gordo county. It enters the county from the southwest, and in the first part of its course it traverses the morainic belt already described. Its course in the moraine is somewhat anomalous. Entering Grant township in section 19 the stream flows northeast and passes into Worth county. Soon after entering Worth its direction is changed toward the east, and after flowing eastward for a few miles it escapes from the moraine and enters upon the area of Iowan drift. Here its course becomes normal for streams in this part of Iowa. It flows southeast, and soon re-enters Cerro Gordo county, crossing the north line of section 5 of Lincoln township. From this point its course is in the main southeast until it leaves the county at the east line of section 36 of Portland township.

Within the moranic belt, in Grant township, the course of Lime creek is very tortuous, since of necessity it winds back and forth to avoid the lawlessly disposed knobs and hills of drift. In this region the channel is new, dating only from the retreat of the Wisconsin ice. It is now a mere shallow trough in loose glacial detritus, showing only an inconsiderable amount of erosion since the stream began work upon it. There is here properly no river valley, nor are there any tributary streams with definitely marked channels. The drainage waters from adjacent lands find their way into Lime creek, sometimes by very roundabout courses, along broad, flat-bottomed swales, or through reedy, ill drained marshes.

In the Iowan drift area, however, Lime creek follows a preglacial valley that was originally in places two or three miles

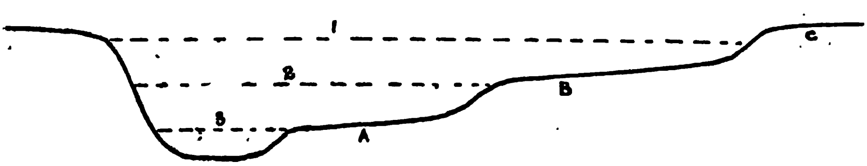


FIG. 18. Profile across valley of Lime creek in western part of Lime Creek township. 1. Width of preglacial valley. 2. Width of valley at close of interglacial stage preceding the advent of the Iowan glaciers. 3. Width of present channel. This channel is a narrow and shallow trough cut in Iowan drift A. Lower plain, only a few feet above level of water in creek. This plain is covered with a thin sheet of Iowan drift and is strewn with large Iowan bowlders that have not been disturbed since they were deposited at the level at which they now lie. B. Terrace into which the interglacial stream cut the valley No. 2. This terrace is underlain by gravel of the age of the Buchanan gravels It is superficially covered with Iowan drift, and is in places thickly strewn with Iowan bowlders. C. Highlands beginning at the northern margin of the preglacial valley, covered with thin mantle of Iowan drift.

in width. In depth the valley varies from twenty to seventy feet. Its history is well recorded in the western part of Lime Creek township. Here the present stream flows in a small, shallow and narrow channel near the southern margin of the valley. The south bank of the stream rises abruptly to a height of thirty or forty feet. On the north side a plain with gentle slope begins near the level of the water and extends back to a terrace that is eight or ten feet in height. At the summit of the terrace there begins another plain that may be two miles or more in width, and is terminated on the north by an irregular line of low hills. The history seems to have been as follows: The preglacial valley (Fig. 18) had a width reach-

ing from the south bank of the present stream to the line of hills which form the northern border of the second plain noted above. The sub-Aftonian drift, if it was ever deposited in this region, cannot be differentiated from the Kansan, but it is certain that at the close of the Kansan stage the old valley was only partially filled with detritus, and an important drainage stream of the subsequent interglacial stage followed the old depression and in part re-excavated the valley. At the beginning of the Iowan stage the re-excavation was far from complete, its amount being represented by the space between the south wall of the valley and the first terrace north of the present stream. The Iowan glaciers deposited only a very thin sheet of drift over this region; but they carried numerous bowlders that are scattered over the whole surface of highlands and lower plains. The plain between the terrace and the channel, and rising only a few feet above the level of the water, is thickly strewn with large Iowan bowlders that have not been disturbed since they were deposited at the level at which they now lie. The present channel is a shallow trough cut in the Iowan drift of this lower plain, and represents the inconsiderable amount of erosion since the withdrawal of the Iowan ice.

The same history is recorded throughout the whole course of the stream in the Iowan drift area, except that during the interglacial stage, between the Kansan and Iowan glacial periods, the stream, for a few miles, was turned aside from the ancient valley and expended its energies in cutting the abandoned, rock-walled channel, already noted, that traverses sections 34 and 35 of Lime Creek township, and a part of section 2 of Mason City. The evidence of the interglacial age of this abandoned channel has been given in connection with the discussion of the topography of the region.

It seems probable that during preglacial and interglacial times the valley of Lime creek accommodated one of the most important streams of northeastern Iowa. After the close of the Iowan stage the Shell Rock river probably took part of

the drainage waters that had previously found their way through various tributaries into the predecessor of Lime creek. At all events there was no pre-Iowan Shell Rock, for this stream follows no valley, and has cut only a shallow trough in the surface of the Iowan drift. Furthermore the Wisconsin drift, particularly the Altamont moraine, choked up that portion of Lime creek valley which doubtless was produced northwestward from the point at which it crosses the northern boundary of Cerro Gordo county. As a consequence the surface waters have been partly turned into new courses, while those that still find their way from the Wisconsin drift area into the old valley are obliged to wander tortuously among morainic knobs, and over areas in which drainage channels are altogether undeveloped. As a result of these changes the relative importance of the stream following this old valley has been greatly diminished.

Shell Rock river.—The Shell Rock river drains the northeastern portion of the county. It flows almost diagonally through Falls township, entering the county a short distance north of Plymouth and leaving it not far from the northeastern corner of Portland township. In its course in Cerro Gordo county the Shell Rock is a comparatively unimportant stream, receiving few tributaries, and having its drainage area confined to a narrow space on each side of the channel. The Shell Rock, as a stream, is new. There is no evidence of any valley older than the Iowan drift. The channel is cut in the drift plain, which, in places, spreads out on either side of the shallow trough in which the stream flows, and without perceptible slope is lost in the unbroken horizon. Fields that give no suggestion of being lower than the adjacent lands are tilled to the water's edge, and from homesteads established on the brink of the stream the view is equally uninterrupted in every direction. The Shell Rock began to flow in its present course after the Iowan ice had disappeared from this region. It is a typical example of a youthful stream. It has cut through the drift and has usually excavated a few feet of

rock, but the work of valley making is only fairly begun. The amount of rock cutting accomplished by the Shell Rock is less than one-third of that performed by the interglacial stream that excavated the abandoned channel near Mason City. It may not be safe from this fact alone to assume that the interglacial period was three times as long as the period since the close of the Iowan glacial stage, for the attitude of the land is an important factor in determining the rate of channel erosion, but there are other corroborative lines of evidence that justify the belief that the interval between the Kansan and Iowan glacial stages was much longer than the time that has elapsed since the close of the Iowan.

Willow creek is a stream of some importance that, with its numerous branches, drains the region between Mason City and Clear Lake. One of its branches affords an outlet for the waters of Clear Lake during periods of excessive precipitation. In the neighborhood of Mason City Willow creek flows in an old valley that has been subject to the same vicissitudes as the valley of Lime creek. It was excavated to a depth of fifty or sixty feet, and was widened by long continued weathering of the valley sides in preglacial times. It was partly filled by Kansan and probably by sub-Aftonian drift, and was in part re-excavated during the interval following the close of the Kansan stage. The bottom of the valley received a thin layer of till, and upon it was deposited many large granite bowlders as a result of the invasion of the Iowan ice. The present channel is a small trough with Iowan drift coming down to its margin.

One of the branches of Willow creek, as already noted, carries off any excess of water from the basin of Clear Lake; the other arises in the imperfectly drained sloughs and marshes that alternate with the knobs of drift in the eastern margin of the hilly country north of the lake. Both have their origin in the Altamont moraine, but the main source of the water supplied to the stream is found in the area between the margin of the moraine and Mason City.

Calmus creek is a stream with a very narrow drainage basin in proportion to its length. It has its origin in a marshy area near the northwest corner of Lincoln township. Its course is nearly parallel to Lime creek, and only a mile or two distant from the larger stream, which it joins in the northern part of Mason City. Except in wet seasons the amount of water carried by Calmus creek is insignificant.

The southern part of the county, east of the moraine, presents extensive reaches of level land in which drainage is not as well established as it is farther north. From large areas the storm waters flow off very slowly, and are finally gathered into a number of small streams that have cut shallow ditch-like channels in the otherwise unbroken plain of Iowan drift. Mount Vernon, Bath, Geneseo, and Pleasant Valley townships are all drained by the numerous small forks of Beaver Dam creek. All of these branches exhibit in the main the characteristics of youthful, prairie streams that have cut only a short distance into the black drift loam. But at a few points some rock cutting has been accomplished, for near Rockwell one of the branches exposes ledges of Owens Grove magnesian shales and limestones; another branch cuts into magnesian shales of the same horizon three miles southeast of Swaledale; in section 35 of Geneseo township the creek flows apparently in a small preglacial, rock-walled valley; and in section 36 of Pleasant Valley township the west branch of Beaver Dam creek cuts into Kinderhook shales and limestones.

Cold Water creek.—Dougherty township is drained by Cold Water creek. This is a small stream in seasons of ordinary rainfall. The headwater branches and the upper portion of the drainage course are defined only as broad swales or sloughs, without any distinct channel cutting through the coarse slough grass sod. Farther down, the channel is better defined.

There are a few drainage channels, not shown on the accompanying map, in the northwestern part of Owen township; there are broad sloughs serving as drainage courses in the eastern part of Owen and Dougherty; but all the southwestern

part of Owen and adjacent parts of Dougherty, Bath and Geneseo townships, belong to a level expanse of rich prairie land in which drainage has been only imperfectly developed.

Drainage of the morainic belt.—The Altamont moraine, occupying the western townships of Cerro Gordo county, is an area that is practically undrained. Lime creek, as already stated, flows through the northwest corner of Grant township, but it occupies the only definitely marked stream channel in the morainic belt north of Clear Lake. In this region Lime creek has no tributaries except so far as the debouching sloughs and marshes afford opportunity for drainage of the adjacent areas. For many miles south of Clear Lake there are no drainage channels, except the broad swales that wind in and out among the hills of drift. Indeed the first definitely marked water course in this direction is found near Thornton in the eastern part of Grimes township.

Source of water supply for Clear Lake.—No surface streams flow into Clear Lake. Union and Clear Lake townships are practically destitute of developed drainage courses. The storm waters flow from the hills to the lower levels, but here they move sluggishly along the bottoms of broad grassy swales or through sedgy marshes and, before being gathered into definite streams, are largely lost, partly by evaporation, and partly by percolation into underground channels. The popular belief among the local inhabitants that Clear Lake, which receives no surface streams, must be fed by springs, is doubtless true, for it would be reasonable to suppose that some of the water that sinks into the ground in the hilly regions north and south of the lake, would find its way along horizons of sand and gravel into the lake bed. The undrained, saucer-shaped marshes or kettle holes characteristic of the morainic area were noted under the head of topography, and it was also noted that the basin of Clear Lake is only a large kettle hole, or depression in the drift materials of the moraine, and is not necessarily connected with any special configuration of the underlying indurated rocks.

Drainage during Wisconsin stage.—Within the limits of Cerro Gordo county it seems clear that few streams of any consequence flowed out from the eastern margin of the Altamont moraine during the period of melting of the Wisconsin ice. The waters from such melting probably for the most part flowed southward along the margin of the ice, inside the moraine, to escape through the marginal ridges of drift at points outside the limits of Cerro Gordo county. Toward the southern extremity of the Wisconsin ice lobe the escaping streams deposited trains and terraces of gravel along their courses. This gravel may sometimes be traced for miles down the valleys in regions outside the lobe of Wisconsin drift, and it may be followed backward into the newer drift region for long distances. In this county, however, there is no evidence of violent stream action and consequent deposition of gravels in connection with the melting of this latest ice sheet, except in the neighborhood of Thornton, and along the west branch of Beaver Dam creek between Thornton and the point at which this stream passes into Franklin county, at the south line of section 36, Pleasant Valley township. The bold topography characteristic of the moraine farther north gives place in Grimes township to more softened and gentler undulations. There is no marked elevation of the morainic belt above the drift areas on either side. The creek in question heads well toward the west side of the moraine, and its valley seems to have formed the most important outlet in the county for the escape of waters from the melting ice sheet. Gravels begin in valleys of the several branches of this creek some distance above Thornton. A very large body of gravel occurs where two important branches come together just below the village. Gravels are strewn all along the creek valley to points beyond the limits of Cerro Gordo county, an important bed occurring in the roadside and adjacent fields a few rods west of the point at which the stream crosses the county line.

GEOLOGICAL FORMATIONS.

General Description.

The geological formations of Cerro Gordo county, while not very numerous, are all of especial interest both from an economic and scientific point of view. The indurated rocks embrace shales and limestones; the superficial deposits are almost exclusively drift. Throughout the greater part of the county the drift covers and conceals the rocks of sedimentary origin. The principal exposures of indurated beds occur along the larger streams and their tributaries in the northeastern half of the county. Exposures of one kind or another are almost continuous along Lime creek throughout its course in the Iowan drift of this region, and Shell Rock river runs over, or between, beds of limestone nearly all the way from Plymouth until it passes into Floyd county above Nora Springs. Near the mouth of Willow creek there are vertical limestone cliffs, and Calmus creek, for a short distance above its mouth, has its channel floored and walled with hard beds of limestone. The following table shows the geological formations recognized in Cerro Gordo county.

GROUP.	SYSTEM.	SERIES.	STAGE.	SUB-STAGE.
Cenozoic.	Pleistocene.	Glacial.	Wisconsin. Iowan. Buchanan. Kansan.	
Paleozoic.	Carboniferous.	Lower Carboniferous, Mississippian.	Kinderhook.	
	Devonian.	Middle Devonian.	Lime Creek.	Owen.
				Hackberry.
			Cedar Valley.	Mason City.

DEVONIAN SYSTEM.

CEDAR VALLEY LIMESTONE.

The lowest beds seen in this county are the equivalent of the upper portion of the Cedar Valley limestone, as this limestone is developed in Johnson and adjacent counties. A line drawn from Iowa City to Mason City is very nearly parallel to the general line of strike of the Cedar Valley and underlying limestones, and hence, although the geological structure is complicated to some slight extent by local folds, equivalent strata are found at numerous intermediate points. The most persistent life zone in the formation,—a zone which, though presenting some biological and lithological variations, is continuous and well marked over a very large part of the area occupied by Devonian strata in Iowa,—is that containing the branching and spherical stromatoporoids characteristic of the beds numbered eight, nine and ten of the general Cedar Valley section of Johnson county.*

Southeast of the Normal School buildings at Cedar Falls this zone of spherical stromatoporoids occurs in the same relative position to other definitely marked life zones, that it occupies at Iowa City. It overlies the evenly bedded and, in general, non-fossiliferous quarry stone, and this in turn overlies the zone of *Acervularia davidsoni*. Omitting intermediate points, the stromatoporoid bed is seen above the quarry stone near Marble Rock. It was this same stromatoporoid bed that some years since was worked for the "coral marble" at Charles City. At the locality last named the matrix is more than usually compact, owing to the very perfect cementation of the material with interstitial calcite. The east end of the wagon bridge over the Shell Rock river at Nora Springs rests on the the same bed of Stromatopora. The bed is again exposed in the low bluff of Lime creek at Portland, and is very conspicuous at the top of Lein Brothers' lime quarry in Mason City. The zone of spherical stromatoporoids varies greatly in thick-

* This volume, p. 71.

ness, even within short distances. It varies also in the genera and species of true corals with which the stomatoporas are associated. It varies in the compactness of the matrix and in the perfection of preservation of its fossils. Toward the south the spherical stromatoporoids are followed in ascending order by beds of white, non-fossiliferous limestone. White limestone charged with stromatoporoids growing in flat, laminar sheets or expansions follow the same bed in Cerro Gordo and Floyd counties. In Johnson county the crinkled stems of two species of Idiostroma sometimes prevail to the almost total exclusion of other forms of stromatoporoids; in Cerro Gordo county Idiostroma is usually absent at this horizon, but a very fine stemmed species occurs abundantly in association with the spherical forms, in the upper part of the Kuppinger quarry, a few rods below the mill on Lime creek in Mason City. In Johnson county a Favosites, or Pachypora, with cylindrical habit of growth and very thick-walled corrallites, occurs in the Stromatopora bed; in Floyd and Cerro Gordo, a related, though different, species of the same genus is found sparingly at this same horizon. In Johnson the bed in question frequently contains large coralla of *Acervularia davidsoni;* in Cerro Gordo *Pachyphyllum woodmani* and a new species of Diphyphyllum take the place of the Acervularia. Ten or fifteen feet above this horizon, however, in beds of white limestone containing laminar stromatoporoids, *Pachyphyllum woodmani* is associated with *Acervularia inequalis*, a very characteristic species, and evidently a highly modified descendant of the species occurring in Johnson county.

TYPICAL EXPOSURES.

The characteristics of the Cedar Valley stage in this county may be judged from a study of the following typical exposures. The Kuppinger quarry, in the east bank of Lime creek, between the bridge and the mill dam in the northern part of Mason City, gives the following section:

		FEET.
7.	Residual clay and drift	4
6.	Somewhat regularly bedded stromatoporoid limestone in which occurs a small Favosites and some laminar stromatoporas associated with many spherical masses of stromatopora with concentric laminæ of growth	3
5.	Reef of stromatoporoids consisting largely of spheroidal coralla with concentric, laminated structure; some of the coralla are more than a foot in diameter. In some cases there are great numbers of very fine stems of a species of Idiostroma. Bedding obscure	5
4.	White or grayish, fine-grained limestone, breaking with conchoidal fracture, very compact; ledges ranging from a few inches to more than two feet in thickness. No traces of fossils, or traces few and very obscure	14
3.	Bluish limestone, flexuous and unevenly bedded	2
2.	Hard, crystalline, grayish dolomite, with occasional streaks of brown and red. In weathered portions of this member the crystals of dolomite are in places very loosely cemented and the rock has the appearance of a friable sandstone. Some beds are vesicular, owing to the solution and removal of fossils. The cavities, however, are lined with crystals to such an extent as to obliterate all evidence of generic or specific characters. Ledges varying from 6 to 36 inches in thickness	8
1.	From floor of quarry to level of stream, covered with talus	2

The crystalline dolomite, No. 2 of the foregoing section, is called sandstone by the quarrymen and masons of the region. Some of the fossil cavities are evidently due to removal of crinoid stems. The bedding is regular, and the stone may be quarried readily in blocks of serviceable size and shape. No. 3 is rather worthless, owing to the irregularities of bedding and the tendency of the layers to break into shapeless pieces. The white, fine-grained limestone, No. 4, shows very regular bedding, the individual layers generally retaining the same thickness for considerable distances. The rock from this member does not resist the weather as well as the dolomite, No. 2, though it is used extensively and serves well for many purposes.

Numbers 5 and 6 together constitute a regular Stromatopora reef. The lower part of the reef shows no bedding planes. At first the stromatoporoids consisted of species growing in spherical or spheroidal masses from a fraction of an inch to more than a foot in diameter, but later, species growing in flat, laminar masses displaced those with the concentric habit of growth. A few colonies of small cylindrical or branching forms of Favosites and Cladopora occur with the stromatopores, but true corals are very rare at this horizon.

FIG. 18. Natural exposure of Cedar Valley limestone at Parker's mill, Mason City. At this exposure the regular stratification of the beds of this formation, is shown, and their superior powers of resistance to effects of weathering, particularly in the dolomitic phase, are well demonstrated.

The lower surface of the Stromatopora bed is strangely cut by a series of ramifying channels apparently accomplished by streams of water flowing between this bed and the underlying white limestone. The streams, however, dissolved and eroded the roof more than they did the floor of their underground channels.

The residual clay, No. 7, at the top of the section is very tough and very ferruginous. It has worked its way downward along joints, and from the joints it has spread out horizontally between layers, so that all openings are filled with it to a depth of many feet from the original surface.

Above the top of the Kuppinger quarry section, the hill rises more than twenty feet. Stromatopores occur at intervals all the way up, but above the level of the quarry the coralla are all of the laminar type. Among the species with horizontal, expansive habit of growth, single coralla may be found measuring from two to five or six feet in diameter. The hillside is partly sodded, and hence no complete section at this point can be made.

Above the mill dam, on the same side of the stream as the Kuppinger quarry, there are exposures of beds 2, 3 and 4 of the preceding section; and on the south side of Calmus creek, not far from its mouth, the same beds have been quarried to a considerable extent.

At Parker's mill on Willow creek, within the limits of Mason City, the picturesque vertical cliffs (Fig. 19) afford a natural section, in which may be noted.

		FEET.
6.	Stromatopora reef, equivalent of No. 5 of the Kuppinger quarry	4
5.	White limestone, somewhat split up by weathering	14
4	Evenly bedded dolomite, in ledges varying from 3 to 30 inches in thickness	12
3.	Impure dolomite, breaking irregularly by exposure to weather, and containing many cavities lined with crystals of calcite	2½
2.	Crumbling, calcareous, granular bed, light gray in color, with many nodular and branching stromatopores, some Favosites and beautiful coralla of *Pachyphyllum woodmani*	1
1.	Argillaceous limestone, dark drab in color, homogeneous, but breaks up on exposure to frost	2

At Lein Brothers lime quarry, in Mason City, the succession of beds already described occurs essentially unchanged. The exposure gives the following section.

		FEET.
4.	Stromatopora reef, rather definitely stratified, some laminar stromatopores, though most are spheroidal in shape. With the stromatopores occur *Pachyphyllum woodmani*, an unknown Diphyphyllum and some species of Cladopora	3

		FEET.
3.	Unstratified part of the Stromatopora reef with spheroidal coralla	5
2.	White limestone	15
1.	Dolomite, blue and gray	4

The quarries of the Belding Stone Co. are located north of Mason City, in the Se. qr. of Nw. ¼ of section 27, Lime Creek township. The beds here show some differences from those observed in the quarries and exposures above described, as will be seen by the following section.

		FEET.
7.	Soil and residual clay from a few inches to	2½
6.	White or grayish limestone, shattered into small pieces; removed as part of the stripping	3
5.	White limestone in thin layers	3
4.	White limestone in layers from 2½ to 10 inches in thickness, good building stone	4
3.	Evenly bedded dolomite, suitable for heavy walls or for cutting into caps and sills; in three ledges 21, 10 and 11 inches respectively in thickness	3½
2.	"Blue cap," a bed that quarries out in shapeless, worthless blocks, in two ledges; an impure dolomite	3
1.	Brown, bluish and gray dolomite in eight ledges, varying from 4 to 13 inches in thickness	5½

The white limestone at the quarry described above lies in thinner layers than the corresponding beds at Mason City. What the quarrymen here call "blue cap," No. 2 of the section, seems to be a local deposit, or at least a local variation in certain layers, in the middle of the dolomitized beds. There is some difficulty in correlating unfossiliferous beds in this region, and the difficulty arises from two causes. First, any given bed may thin out within very short distances, as is well illustrated in figure 20, and ledges that are separated from each other by several feet of strata at one exposure, may be in contact at exposures not far removed. Second, the process of dolomitization has affected the beds differently in different localities, so that ledges of fine-grained, white limestone in one place may be represented by coarse, granular dolomite in another.

At the quarries of the Mason City Stone Co., in the Ne. qr. of the Nw. ¼ of section 34, Lime Creek township, the dolomitized beds have an aggregate thickness of nineteen feet. Above the dolomite are twelve feet of white limestone. A pit sunk below the bottom of the quarry reveals an argillaceous limestone similar to No. 1 of the Parkers' Mill section, and probably its equivalent.

The Mason City Quarry Co. have two openings in the Nw. qr. of Ne. ¼ of section 27 of the same township. The work here has not been carried very far back from the natural exposure, and it is probably due to this fact that the layers are in general thinner than at the other quarries described. The beds quarried consist partly of dolomite and partly of the white, non-dolomitized ledges. Certain beds of the dolomite show the effect of weathering much more than others. In ledges twelve to fifteen inches in thickness the cementing material whereby the individual crystals are held together has, in some instances, been removed, and the rock presents the very delusive appearance of a friable, crumbling sandstone, a fact which may in part account for the popular application of the term sandstone to all the dolomitized beds.

At Portland, about four miles southeast of Mason City, the east end of the wagon bridge over Lime creek rests on ledges of limestone forming a vertical cliff. A short distance below the bridge the following section, with the exception of No. 6, was noted.

		FEET.
6.	Dolomitized bed with casts of thin laminar expansions of stromatoporoids, exposed between bridge and mill	5
5.	Coarse, granular dolomite in thin layers	3
4.	White limestone with some stromatopores, the definitely bedded portion of the Stromatopora reef	2
3.	Stromatopora reef, with spheroidal coralla, but more perfectly stratified than at most exposures	4
2.	White limestone, evenly bedded	3
1.	Dolomitized limestone in heavy layers	13

No. 1 in the above section is the equivalent of the dolomite quarried so generally near Mason City. No. 2 represents the fourteen or fifteen feet of white limestone of the Mason City exposures. Nos. 3 and 4 will be recognized as the Stromatopora beds of other localities; while Nos. 5 and 6 are modified representatives of non-dolomitized beds overlying the Stromatopora reef and containing laminated stromatoporoids in the hill above Kuppinger's quarry. Above the bridge the vertical cliff shows the rapid feathering out of certain beds. Strangely enough it is here the most persistent of all the

FIG. 20. Exposure of Cedar Valley limestone near Portland, showing how beds may sometimes "feather out" abruptly. The thinning out of the strata affected is most pronounced near the middle of the view.

beds (Nos. 3 and 4 of the section) with spherical stromatoporoids, that disappear. No. 5 is bent down abruptly (Fig. 20) to rest on the white limestone, and No. 6, five feet in thickness, appears above it.

Exposures of limestone beds, equivalent to those above described, occur at intervals along Lime creek below Portland, for a number of miles. Less than half a mile below the Portland bridge, bed No. 6 of the Portland section appears in its normal relations, and contains the characteristic laminar

forms of Stromatoporas. Lithologically, however, its characters are wholly different. It is here an unaltered, white limestone without signs of dolomitization. A mile and a half farther down the stream, in the Se. qr. of Ne. ¼ of section 29, Portland township, an exposure between the creek and the roadway gives—

		FEET.
5.	Laminated Stromatopora bed, not dolomitized	5
4.	Dolomitized bed, equivalent of No. 5, of Portland section	3
3.	White limestone with some nodular stromatoporoids	1
2.	Stromatopora reef, the unstratified bed of spherical stromatoporids in upper part of Kuppinger's quarry	4
1.	White, evenly-bedded limestone, exposed to level of water	4

For the next two miles and a half in going down stream there are no exposures of any consequence. No beds higher than No. 5 of the last section were seen until the cliff of Lime creek shales was encountered in the northwest quarter of section 35. The shales here come down to the level of the water and the underlying limestone was not seen. There cannot, however, be any great thickness of limestone intervening between the top of No. 5 of the section last described and the base of the shales.

While the bed of laminated stromatoporoids between Portland and the exposures of Lime Creek shales in section 35 of Portland township nowhere exceeds six or eight feet in thickness, the equivalent bed above the Kuppinger quarry has a thickness of about twenty feet. Again, while the shales in Portland township seem to rest on the bed of laminated Stromatoporas, it is still true that this laminated bed is not the highest member of the Cedar Valley limestone. At Nora Springs, a short distance east of the east line of Cerro Gordo county, there are some exposures of very great interest. In the first place the reef of spheroidal stromatoporas is unusually well developed. It rests as usual on white, non-dolomitized limestone. The lower division, crowded with the characteristic spheroidal coralla, is eight

feet in thickness; the upper portion, showing more definite bedding, is nearly as thick. In the bluff, south of the town, on right bank of the Shell Rock river, there are, above the reef bed, layers corresponding to Nos. 5 and 6 of the Portland section, and these are followed in ascending order by ten feet of soft, yellowish, shaly beds; six feet of light reddish-brown argillaceous limestone, regularly bedded, and quarried for building purposes; five feet of impure, earthy dolomite containing casts of Spirifer and Orthis; and then in the debris on the hillside farther up there are many loose fragments of *Actinostroma expansum* Hall and Whitfield sp., which marks a horizon not previously noted in this report.

The entire section at Nora Springs would, therefore, be—

		FEET.
7.	Horizon of *Actinostroma expansum*, not exposed, but fragments of Actinostroma are found in debris on hillside	
6.	Earthy dolomite, with casts of Spirifer, Orthis, etc.	5
5.	Reddish brown, regularly bedded, argillaceous limestone	6
4.	Soft, yellowish, shaly beds	10
3.	Beds corresponding to Nos. 5 and 6 of the Portland section	5
2.	Stromatoporoid reef	14
1.	White or light gray limestone, regularly bedded, partly brecciated	16

West of Rockford in Floyd county there are exposures along Lime creek, which show the earthy dolomite seen near Nora Springs, with casts of brachiopods and other organic types. It is here only a few feet above the level of the water. Above this lies in place the Actinostroma bed, four feet in thickness. Some of the massive coralla occupy nearly the whole thickness of the bed, and have horizontal dimensions of eight or ten feet. The Actinostroma bed is overlain by a thin bed of unfossiliferous white limestone. This is followed by ten feet of yellow laminated shale; and the shale is in turn overlain by a single layer, six feet in thickness, made up of thin, sinuous laminæ of Stromatopora, united at intervals to form a

mesh-like plexus when seen in vertical section. The plexus of stromatoporoids is embedded in a yellow matrix. About a mile west of the section described above, the well-known Rockford exposures of the Lime Creek shales occupy a position consistent with the view that they rest on the bed last described. At all events nothing higher than this bed is at present known beneath the Lime Creek shales, and it may, therefore, provisionally be regarded as the uppermost member of the Cedar Valley stage.

Cedar Valley limestones are exposed along the Shell Rock river, at short intervals, from near Plymouth until the stream passes into Floyd county. In the northwest quarter of section 17, Falls township, beds of hard, crystalline, dark gray dolomite are exposed in bank of river with an aggregate thickness of about eight feet. The layers are intersected by many seams, and there are numerous pockets filled with calcite. The strata dip up stream, and beds not seen at the first exposure appear a few yards below. A light gray dolomite, more nearly resembling the dolomitized beds at Mason City, underlies the darker phase. The darker beds are in thin layers, and some near the top of the exposure contain obscure traces of a fossil resembling Strombodes. The beds at this locality are the equivalent of bed No. 5 of the Portland section. This member is, however, much thicker here than at Portland and has some beds heavy and compact enough for use as building stone.

Along the Shell Rock the beds are very much folded. A very sharp arch is seen north of the center of section 17, and at another fold, one-half mile south, the flank of the arch dips at an angle of 22°. The crown of one of these small arches in section 17 reveals the beds below the dolomite noted above. At level of stream there is a white, regularly bedded limestone which, a few feet higher, is overlain by the Stromatopora reef of the Kuppinger quarry. The white limestone which is fourteen feet thick at Mason City is, near the west line of section 16, reduced to two feet, and is underlain, as shown in one of the folds, by the Mason City dolomite.

[illegible] there is a small quarry [illegible] the quarry dip south- [illegible] The exposure shows.

	FEET
[illegible]	4
[illegible]	4

[illegible] limestone have been crushed [illegible] in connection with the process [illegible] fragments of the underlying [illegible]

[illegible] Rock Falls there is a good [illegible] section.

	FEET
[illegible]	1
[illegible]	8
[illegible]	
[illegible]	2
[illegible]	2

[illegible] Rock Falls [illegible] section.

[illegible]

in Lime Creek and Lincoln townships. These show a very interesting progressive modification of certain beds toward the northwest. At the bridge over Blake creek, near the northeast corner of section 28, Lime Creek township, the exposures present the phases observed near Mason City and Portland. A section here gives:

		FEET.
5.	Dolomitized phase corresponding to No. 5, of the Portland section	4
4.	White limestone, with some stromatoporoids	6
3.	Reef with spherical stromatoporoids	4
2.	Regularly bedded white limestone	10
1.	Dolomite, exposed to bed of creek	1

Above the bridge the cliff shows a tendency to cavernous undermining, owing to the greater destructibility of the white limestone. The reef of Stromatopora forms the roof of the caverns. All the beds are affected by one of the small folds so common in the limestones of this stage throughout Cerro Gordo and adjacent counties.

About two miles west of the Blake creek bridge, near a small schoolhouse in section 19, the Stromatopora reef occurs at the level of the water in Lime creek, and is followed by the usual beds of white, sparingly fossiliferous limestone. Two and a half miles farther up the creek, in section 14 of Lincoln township, some interesting exposures were observed. There are many strong local dips and short folds. The Stromatopora reef is frequently exposed, and the white overlying limestone is here quite fossiliferous. Among the genera noted were Acervularia, Pachyphyllum, a peculiar Diphyphyllum, Syringopora, Cladopora, Atrypa and Straparollus.

At Lincoln mills, in section 15, the reef bed is exposed at the level of the water, and the overlying strata contain the same fauna as the corresponding ledges in section 14. Below the mill there are two small folds or anticlines with crests twenty rods apart, and the fossiliferous white limestone is, in places, quite distinctly brecciated. A thin bed of dolomite above the Stromatopora reef is a feature more or less constant at all exposures. It apparently corresponds to bed No. 5

at Portland. At the east end of the bridge, three-fourths of a mile above the mill, there is an exposure showing a reef rich in true corals. The beds are made up chiefly of masses of Acervularia, Diphyphyllum and Cladopora; yet in many instances the Diphyphyllum has grown around a mass of Stromatopora, and spheroidal stromatoporas make up no inconsiderable portion of the entire deposit. Colonies of this peculiar Diphyphyllum, showing evidences of luxuriant growth under what must have been very favorable conditions, become more numerous as the beds are traced up Lime creek, towards the northwest. Small, dwarfed colonies, with stems rarely more than an inch in length, are found rather sparingly in the reef bed and in overlying layers at Nora Springs, Portland and Mason City. Larger and more vigorous colonies, associated with a greater number of true corals, are furnished by the exposures in the western part of Lime creek, and eastern part of Lincoln township. At the bridge above noted corals are numerous, and the Diphyphyllum occurs in aggregations of long, slender, flexuous stems, with individual corallia [illegible] more than a foot in diameter. The conditions that gave Diphyphyllum unusual advantages at this locality seem to have favored other corals also and Cladopora, as well as [illegible] of other genera, flourished more luxuriantly [illegible].

[illegible] west side of section [illegible] section [illegible] Lincoln [illegible] exposures which [illegible] Owen's Grove [illegible] beds are [illegible] Stromatopora [illegible] beds at the [illegible] a small [illegible]

Diphyphyllum and other corals has been changed to a coarse granular dolomite, and some of the non-dolomitized layers had been superficially divided into irregular polygonal areas by mud cracks, as if by exposure to atmospheric drying at the time of their formation. All the phenomena seem to imply that the conditions of deposition even in beds that are practically continuous, varied considerably within very short limits.

Along the abandoned channel of Lime creek (Fig. 11), in sections 34 and 35 of Lime Creek township and section 2 of Mason township, the beds as usual exhibit a series of sharp folds; and in the troughs or synclines layers aggregating thirty or forty feet are exposed above the horizon of the Stromatopora reef. In these beds stromatoporoids with laminar expansive habit of growth are very common, and along certain zones *Pachyphyllum woodmani* and *Acervularia inequalis* occur abundantly. Among the stromatoporoids with horizontal laminar mode of growth are some coralla of *Actinostroma expansum.* These coralla are, however, very much smaller than the gigantic coralla of the same species along Lime creek near Rockford, and would seem to indicate growth under less favorable conditions. The argillaceous, dolomitic beds, with casts of brachiopods and other fossils, found below the Actinostroma horizon at Nora Springs and Rockford, seem to be absent in the exposures near Mason City. The evidence of local distribution of certain beds, of rapid thinning out of others (Fig. 20), of faunas more or less localized on account of rapidly varying biotic conditions in the seas in which the beds were deposited, are everywhere apparent, and constitute one of the striking peculiarities of this most interesting region. Only a very generalized section of Cedar Valley limestones of Cerro Gordo and adjacent counties can be given, for the same bed varies in thickness and in lithological characters within short distances, and there is scarcely a single bed that can be said to be constant over any considerable area. The greatest variations occur in the beds above the

Stromatopora reef (bed No. 5 of the Kuppinger quarry section near Mason City).

GENERALIZED SECTION OF CEDAR VALLEY LIMESTONES IN CERRO GORDO AND ADJACENT COUNTIES.

		FEET.
7.	Horizon of *Actinostroma expansum* and the variable beds above it at Rockford, Nora Springs, and in the hillside north of the abandoned channel of Lime creek near Mason City	22
6.	Argillaceous and argillo-dolomitic beds with casts of fossils in uppermost layers; best developed at section south of Nora Springs; apparently absent at Mason City	21
5.	Beds with laminar stromatoporoids and coralla of Acervularia, Pachyphyllum and a peculiar Diphyphyllum; Diphyphyllum best developed in Lincoln township, in which region the bed contains *Atrypa reticularis;* more or less of the beds dolomitized at different exposures	15
4.	Reef of nodular or spheroidal stromatoporas, equivalent to beds five and six of the Kuppinger quarry section. This bed attains its greatest thickness east of Cerro Gordo county, as at Charles City and Nora Springs	15
3.	White or light gray, fine-grained limestone, regularly bedded, unfossiliferous, in ledges ranging to more than two feet in thickness	14
2.	Dolomite more or less pure and crystalline; generally in compact, regular beds, but very variable in respect to aggregate thickness as well as thickness and composition of individual layers	20
1.	Earthy dolomite, including near the top, at Parker's mill, a thin calcareous bed, with peculiar stromatoporoids and *Pachyphyllum woodmani;* otherwise unfossiliferous; greatest thickness exposed at Vermilya's bluff (Fig. 14)	20

The entire section of Cedar Valley limestone in the region under discussion lies above the horizon of *Spirifer parryanus* and the reef of *Acervularia davidsoni*, as seen near Waterloo, Littleton and Iowa City. Beds 1, 2 and 3 of the above general section are represented in Johnson county, if at all, by more or less fossiliferous beds not exceeding fifteen feet in thickness.

LIME CREEK SHALES.

At what is popularly known as the Hackberry Grove clay bank, in the northwest quarter of section 35 of Portland township, the Cedar Valley limestones are overlain by the shales and shaly limestones of the Lime Creek stage. On the right bank of Lime creek, in this locality, there is an escarpment, more than seventy feet in height, composed of the Lime Creek formation throughout practically its entire thickness (Fig. 21). In the bed of the creek there are some ledges of

Fig. 21. Exposures of Lime Creek shales at Hackberry Grove. The fossil-bearing member, consisting of calcareous shales and shaly limestones, is seen near the top of cliff. As a result of weathering this member produces a large number of calcareous nodules which are strewn over the talus slope and conceal, to a large extent, the edges of the blue and yellow, argillaceous, non-fossiliferous beds.

limestone of the Cedar Valley stage, but the shales come down almost or quite to the level of the water, and the talus of shaly material obscures the line of contact between the two formations. The section so far as it can be made out from the weathered surface which, at almost every point, has more or less of overwash from higher beds, is as follows.

		FEET.
4.	Brown, yellowish brown, and gray limestone in several layers, containing many of the fossil species found in the underlying shaly limestone; upper bed crowded with a very slender stemmed Idiostroma	4
3.	Yellowish, very calcareous shales, with bands of shaly limestone; weathering partly into clay and partly into small chips or nodules; very rich in beautifully preserved fossils, particularly brachiopods and corals, a number of interesting species of stromatoporoids being included with the corals	20
2.	Yellow argillaceous shales, weathering as does the blue clay below, and free from fossils	10
1.	Bluish, argillaceous shales, weathering into a smooth, plastic clay, unfossiliferous	40

Along Owen creek, in section 31 of Portland township, there are a number of exposures of the same shales seen at Hackberry Grove. There are also exposures in the roadway north and south of the point at which this creek crosses the east line of section 31. South of the creek, near the east side of the section, there is a natural exposure in the rather steep hillside, which shows the blue unfossiliferous shales near the base, and the calcareous fossiliferous beds above. The formation seems to be, on the whole, somewhat thinner here than at Hackberry Grove, but the succession of beds is the same and the fauna of the fossiliferous stratum is identical. A road cutting on the section line, a few rods southeast of the exposure, reveals the calcareous, fossil-bearing beds. At the exposure on the hillside there is evidence of a strong dip to the west; in the road cutting the dip seems to be to the south. The shales here dip in fact to the southwest, the southern component being a little more than fifty feet to the mile, and the western component equally as great. Following up the creek there are outcrops of the shales at intervals; and owing to the fact that the valley slopes to the northeast while the shales dip in the opposite direction, only about half the thickness of the shaly fossil-bearing member of the section rises above the level of the creek bed at the first outcrop west of the half-section line. Farther up, the Idiostroma-bearing limestone—

No. 4 of the Hackberry section—appears nearer and nearer the bottom of the valley, until finally at a small quarry near the west line of the section, this limestone occurs in the very bed of the creek and forms the floor over which the water flows. A quarry opened in the low bluff at this point works beds that lie above the uppermost member of the Hackberry Grove section. The layers exposed by the quarry are yellowish in color, and are made up of magnesian shales and soft argillaceous dolomites. Only a few of the layers furnish building stone. Fossils occur, but they are all in the form of mere casts or impressions. So far as they can be identified the fossils are the same as species found in the calcareous shaly layers below the Idiostroma-bearing limestone, and therefore the beds exposed in the quarry must be regarded as the upward continuation of the Lime Creek formation. The thickness of the magnesian shales and argillaceous dolomites at the quarry is about thirty feet. In the talus-like debris on the hill slope above the quarry there are fragments of limestone along with specimens of a species of Acervularia not before observed. There are probably twenty feet of strata indicated above the level of the quarry, and this too may, for the present, be regarded as a continuation of the same formation. Since no Devonian beds, known to be higher in the geologic column than the Acervularia-bearing limestone above the Owen creek quarry, were seen at any point, the strata belonging to the Lime creek stage may be arranged as follows.

GENERAL SECTION OF LIME CREEK SHALES.

		FEET.
6.	Calcareous beds, light gray in color, containing a hitherto unnoted species of Acervularia	20
5.	Magnesian shales and argillaceous dolomites, with impressions and casts of fossils among which are very large individuals of *Naticopsis gigantea*	30
4.	Limestone with slender Idiostroma (No. 4, of Hackberry section)	4
3.	Fossiliferous calcareous shales (No. 3, at Hackberry)	20
2.	Yellow, non-fossiliferous shales	10
1.	Blue, non-fossiliferous shales	40

Nos. 1, 2 and 3 will hereafter be referred to as the Hackberry beds of the Lime creek formation; Nos. 4, 5 and 6 will be called the Owen beds.

The blue shales, No. 1 of the Hackberry beds, are exposed at a few points in the county. The best exposure is the typical one at Hackberry Grove. They outcrop at two of the exposures on opposite sides of Owen creek, in the east half of section 31 of Portland township. They are again seen at the foot of a low bluff, on the south side of Willow creek, in the southwest quarter of section 5 of Mason township. They are exposed artificially in the clay pit of the Mason City Brick & Tile Co. at Mason City. The yellow shales, No. 2, have about the same exposures. The shaly, calcareous fossiliferous division, No. 3, is seen at Hackberry Grove, where the largest and most important exposure occurs. There are half a dozen or more typical outcrops along Owen creek in the southwest corner of Portland township, and the typical phase of the same bed, rich in beautifully preserved fossils, is seen on a hillside in the Se. qr., Ne. ¼ of section 24 in Owen township. Roadways, either by natural erosion or artificial excavation, have been cut into this stratum along both the east and west lines of section 32 of Portland township, and on the county line, along the east side of section 24 in Owen. The same phase is found near the southeast corner of the county.

At least two phases of the fossil-bearing stratum of the Hackberry beds must be distinguished. The typical phase is a calcareous shale interstratified with shaly limestone and very rich in fossils. The brachiopods and corals are preserved in remarkable beauty and perfection. Representatives of the Mollusca usually occur in the form of casts. This phase is seen at Hackberry Grove, along Owen creek at Owen's Grove, and at all outcrops south of the two points mentioned. As this bed is traced northwest from Hackberry and Owen's Grove, it assumes a new phase, becoming more magnesian and preserving fossils only in the form of impressions or imperfect

casts. This magnesian phase is seen above the blue shales, along Willow creek in the western part of section 5 of Mason township. It is exposed in the railway cut west of the Chicago, Milwaukee & St. Paul depot, in Mason City, within a few rods of the point where the yellow and blue unfossiliferous shales are worked by the Mason City Brick & Tile Co. It crops out at a dozen points or more in the road between Mason City and Clear Lake, becoming, however, less shaly and more dolomitic toward the west. The last exposure noted in this direction occurs near the east line of section 17 in Lake township, about two miles east of Clear Lake. The beds here are a moderately firm and rather crystalline dolomite and have been quarried on a small scale for building stone. All the fossils, as is quite usual in dolomites, are casts, but owing to the greater firmness of the rock they are much better preserved than in the more shaly portions near Mason City.

The outcrops of the Owen beds occur chiefly in the southeastern part of the county. Only a few of the more characteristic exposures need be mentioned. That which may serve as the type, the quarry on Owen creek near the west line of section 31, Portland township, has already been mentioned. There is another excellent exposure of the same beds, also quarried for building stone, about a mile and a half southeast of the Owen creek quarry. At this point (Nw. qr. of Sw. ¼ of section 5, Owen township) the rock is harder, and it lies in thicker layers than at the typical exposure. The level here is nearly the same as that at which the fossiliferous member of the Hackberry beds occurs a little more than a mile directly north, at which point, as already noted, the road cuts through this bed, exposing nearly its entire thickness and revealing a southerly dip of more than fifty feet to the mile. This dip carries the Hackberry shale below the bottom of the small valley in the side of which the outcrop in section 5 of Owen township occurs. At this last named locality the quarry stone is overlain by a light colored limestone containing the species

of Acervularia characteristic of this horizon. This limestone is exposed in the road for some distance south of the quarry.

Owen beds, exhibiting the yellow magnesian phase overlain by limestone, are exposed on and near the county line in the southeast quarter of section 25 in Owen township. North of Rockwell they are seen along the west line of section 35 of Bath township; and in the neighborhood of Rockwell in Geneseo township, there are outcrops of considerable interest. They afford here a quarry stone of fair quality, and beds have been worked at a number of points. The typical fossils are large casts of *Naticopsis gigantea* H. and W., in the magnesian beds, and Acervularia (species undetermined) in the overlying lighter limestone. In the upper part of the quarries, above the dolomitized beds, there are many colonies of a thin laminar stromatoporoid. There is a small quarry in section 26 of Geneseo township and near the southeast corner of section 36, on land of Mr. Bokemeier, there are two or three exposures that have been quarried to some extent. These exposures offer nothing especially new. The beds consist of soft, yellow, magnesian shales with interstratified beds of earthy dolomite and are overlain by limestone. In the magnesian beds casts of very large individuals of the form described by Hall and Whitfield as *Naticopsis gigantea* occur, as they do at all the other exposures of beds belonging to this horizon, and with them are casts of *Spirifer whitneyi* and some other characteristic brachiopods of the Lime creek stage. A portion of a large Cyrtoceras, flattened by pressure, was found in the loose material of the quarry, and specimens of the large, gastropod with elongated spire, that has been erroneously described* as *Loxonema gigantea*, occur occasionally.

* Am. Nat. vol. 22, p. 445, Phila., 1888 The forms described as *Loxonema gigantea*, *L. crassum* and *L. owenensis*, are not even distantly related, generically, to Loxonema. In the structure and composition of the substance of the shell, the great thickness of the shell, the characteristics of the aperture, and the surface markings, they belong with the peculiar form called *Naticopsis gigantea* by Hall and Whitfield; and it is quite possible that this group will have to be assembled under a new generic description. The proposal of a new name and definition of the genus is, however, left for those who have the requisite expert knowledge and who find delight in such things.

FAUNA OF LIME CREEK SHALES.

The fauna of the Lime creek shales is of such general geological interest as to deserve more than a passing notice even in a work devoted chiefly to the economic side of geology. The following list of species which might be greatly extended, gives the more common and conspicuous forms. It will afford some knowledge of the general aspect of this most interesting assemblage of Devonian types.

Stromatoporella incrustans Hall and Whitfield.
S. solidula H. & W.
Parallelopora planulata H. & W.
Acervularia inequalis H. & W.
Cyathophyllum solidum H. & W.
Pachyphyllum woodmani White.
P. solitarium H. & W.
Campophyllum nanum H. & W.
Ptychophyllum ellipticum H. & W.
Strombodes johannis H. & W.
S. multiradiatum H. & W.
Cystiphyllum mundulum H. & W.
Aulopora saxivadum H. & W.
A iowensis H. & W.
Alveolites rockfordensis H. & W.
Crania famelica H. & W.
Stropheodonta arcuata Hall.
S. calvini Miller.
S. canace H. & W.
S. variabilis Calvin.
S. perplana var. *nervosa* Hall var.
Strophonella reversa Hall.
S. hybrida H. & W.
Orthothetes chemungensis Conrad.
Productella hallana Walcott.
Orthis (*Shizophoria*) *impressa* Hall.
Camarotœchia contracta var. *saxatilis* Hall.
Pugnax altus Calvin.
Pugnax ambiguus Calvin.
Gypidula comis Owen.
Dielasma calvini H. & W.
Atrypa reticularis Linnæus.
Atrypa aspera var. *hystrix* Hall var.
Spirifer whitneyi Hall.
S. orestes H. & W.

S. fimbriatus Conrad.
S. macbridei Calvin.
S. cyrtinaformus H. & W.
S. hungerfordi Hall.
Crytina hamiltonensis var. *recta* Hall.
Paracyclas sabini White.
Paracyclas elliptica Hall?
Naticopsis gigantea H. & W.
Orthoceras sp.
Crytoceras sp.
Goniatites sp.

About the only fish remains observed were fragments of plates of Arthrodires. The Goniatites mentioned is represented by a single imperfect specimen collected by Harold M. McLaughlin, of Mason City. It indicates a species as large as *G. ixion* Hall, but differing from that species in the character of the siphonal lobe.

As shown in 1878* the Lime creek fauna is more closely related to the fauna of the Independence shales than to any other. The following characteristic species are common to the two formations.

Pachyphyllum solitarium H. & W.
Stropheodonta arcuata Hall.
S. calvini Miller.
S. canace H. & W.
S. variabilis Calvin.
Strophonella reversa Hall.
Productella hallana Walcott.
Orthis (Schizophoria) impressa Hall.
Pugnax altus Calvin.
P. ambiguus Calvin.
Atrypa reticularis Linne.
Atrypa rspera var. *hystrix* Hall var.
Cyrtina hamiltonensis var. *recta* Hall.

To this list may possibly be added *Gypidula comis*. This species is found typically developed in the Wapsipinicon stage, but in general outline and expression it here differs conspicuously from the forms referred to this species from the Lime creek formation. The species does not occur in the Cedar

*Calvin, Bull. U S. Geol and Geo. Sur., vol. IV, pp. 725-730. Washington, 1878.

Valley limestones. In the Independence shales, however, there is a small species, *Gypidula munda* Calvin, that differs from the Lime Creek form chiefly in its smaller size. The form referred to above as *Pugnax altus* is a small acuminate variety of *Pugnax pugnus* Martin; and while this last named species occurs in the State Quarry beds of Johnson county, it is there strikingly different from the identical varietal forms that occur in the two shaly formations under consideration.

A few species, some of them, however, having so wide a range geologically and geographically as not to be very characteristic, are common to the Cedar Valley limestones and the overlying shales. These embrace:

Acervularia inequalis H. & W.
Pachyphyllum woodmani White.
Productella hallana Walcott.
Orthis (*Schizophoria*) *impressa* Hall.
Atrypa reticularis Linne.
Spirifer whitneyi Hall.
Spirifer fimbriatus Conrad.
Cyrtina hamiltonensis var. *recta* Hall.

Acervularia inequalis and *Pachyphyllum woodmani* are found in a zone immediately beneath the Lime Creek beds, and not very far outside the geographical area in which the shales are distributed. *Productella hallana* and *Spirifer whitneyi* have been collected, but in very small numbers, in the Cedar Valley limestones near Iowa City. The others range through several life zones, and are found distributed over large areas. Faunally, therefore, the relations of the Lime Creek shales are more intimate with the Independence shales than with any other formation in Iowa. During the time represented by the shales and limestones which lie between the Independence and the Lime Creek shales the peculiar fauna of the lower shale horizon, adapted to life on a muddy sea bottom, persisted in some congenial localities at present unknown, suffering in the mean time only a very slight amount of modification, and again appeared, reinforced by a number of other species,

when the sea bottom offered conditions favorable to its success.

The fauna of the Owen beds is much less prolific in species than that of the Hackberry beds. The form called *Naticopsis gigantea* H. & W. is apparently more common than in the underlying zone. With it, as already noted, are associated one or two related species with more elongated spires. There are some casts and impressions of brachiopods and other types, but no particular species can be said to be common. A species of Acervularia with thin non-corrugated walls bounding the individual corallites, and with thin septa, few in number and rather sparingly carinated, occurs in limestone above the magnesian beds. Probably the highest zone of the Owen beds is exposed along Beaver creek, in the southeast quarter of section 35, Geneseo township. Here the rock is a rather hard, brittle limestone, resembling some phases of the Cedar Valley stage, and the rather meager fauna embraces some stromatoporoids, a Cladopora and a rather small form of *Atrypa reticularis*.

CARBONIFEROUS SYSTEM.

KINDERHOOK STAGE.

Strata of the Kinderhook stage of the Lower Carboniferous series are exposed along Beaver Dam creek in section 36 of Pleasant Valley township. Where the county line road, on the south side of the section, crosses the creek, the Kinderhook beds are composed of soft, shaly, magnesian limestone; but in Franklin county, a short distance south of the road, beds that occupy a higher position are exposed in the sides of the valley, and these are firm enough to afford quarry stone suitable for bridge piers, foundations and other rough masonry. An Athyris resembling *Athyris proutii* Swallow, a Productus related to *P. punctatus*, and Orthothetes sp. are the characteristic fossils. The next exposures east of the Kinderhook outcrops are the Devonian beds already noted on Beaver creek. The contact of the Carboniferous with the Devonian was not

observed, but the line of overlap lies between the two localities last named.

PLEISTOCENE SYSTEM.

There are few good sections of the Pleistocene deposits of Cerro Gordo county available for study, but this disadvantage is partly compensated for by the manner in which the different formations of this system are deployed and present themselves at the surface in different parts of the county. An area approximately equal to three-fourths of the county, embracing almost all excepting the western tier of townships, is occupied, superficially, by Iowan drift, while the townships excepted are characterized by deposits of Wisconsin age. It is very probable that the Iowan drift was spread over the entire area and now underlies the Wisconsin in the western townships; and it is also probable that long before the Iowan glaciers invaded the state, drift of Kansan age formed the superficial deposits of this entire region. Here, however, the Kansan drift is not well differentiated as a distinct sheet of till, as it is in Johnson and adjacent counties. Of the sub-Aftonian or pre-Kansan drift there is at present no reliable evidence.

KANSAN DRIFT.

The Kansan drift, although not differentiated in actual sections, is indicated in two ways. First, the preglacial valley of Lime creek is in places from one to three miles in width; and there is very conclusive evidence that it had been nearly filled with a considerable body of drift, and was later partly re-excavated, before the Iowan till was deposited. This evidence is given in some detail in connection with the discussion of the genesis of the topography of the Lime creek valley. Second, at many points in the valley of Lime creek, and along some of the tributary streams, there are extensive deposits of gravel underlying drift of Iowan age. This gravel is composed of drift pebbles mingled with more or less of sand, and it had its origin in an old drift sheet which preceded the

Iowan age. The gravel beds may reasonably be correlated with the Buchanan gravels, and the drift sheet from which they were derived may in the same way be correlated with the Kansan. At all events Cerro Gordo county was overspread by a sheet of till older than the Iowan, and the fact that the Kansan stage was the time of maximum glaciation for this continent, and that, during this stage, the ice sheet was practically continuous over the whole glaciated area from the eastern part of Nebraska and the Dakotas to the Atlantic ocean, would lend support to the view that a part at least, if not all, of this earlier drift belongs to the Kansan age. This does not preclude the possibility of a pre-Kansan or sub-Aftonian invasion of the region by glacial ice. Indeed the known distribution of the pre-Kansan drift renders it extremely probable that Cerro Gordo county has two sheets of till older than the Iowan.

BUCHANAN GRAVELS.

The stage of the Buchanan gravels* is represented by extensive gravel deposits in the valley of Lime creek, and by similar deposits along Blake creek and other tributaries. The main bodies of these gravels were deposited in the partly filled preglacial valley of Lime creek. They underlie a large area on the north side of the stream in Lime Creek and Lincoln townships, occupying the level space (B. Fig. 18) south of the highlands (c) which mark the boundary of the preglacial valley. Good exposures are seen at various points north of the road near Lincoln mills, in section 15 of Lincoln township; and in section 10 of the same township there is a pit, worked for road material, that shows above the gravel a thin sheet of Iowan till with characteristic granite bowlders. Wells and other excavations reveal underlying gravel throughout the whole plain south of the highlands already noted. Blake creek in Lime Creek township has cut its valley through the

*The Buchanan Gravels, etc, by Samuel Calvin. Am. Geologist, vol. XVII, p. 76. Feb, 1896. Journal of Geology, Editorial, vol. IV, p 872. October-November, 1896. Fifth Annual Report of the State Geologist (this volume), p. 18.

thin sheet of Iowan till and exposed the same gravels at various points, good outcrops occurring north of the center of section 16. The higher ground on either side of the shallow valley is, in places, thickly strewn with Iowan bowlders.

A rather sandy phase of the gravels is worked extensively for ballast by the Chicago, Milwaukee & St. Paul railway, in the southwest quarter of section 2 of Mason township. There are exposures in the northern part of Mason City on the west side of Lime creek, and from one of these, located near the greenhouse, workmen some time ago obtained the horn of a reindeer. The gravel in the northern part of the city is rather coarse, but just east of the city the material is much finer, and the beds have been worked for building sand. The sand, however, contains more or less of gravel; and near the base of the deposit there are many large slabs and fragments of limestone. Gravel beds of varying degrees of fineness are distributed along the valley of Lime creek throughout its whole extent in Cerro Gordo county. The old pre-Kansan valley, only partially filled with drift, seems to have carried torrents of water from the melting Kansan ice. The torrents were loaded with gravel and sand, and doubtless with finer material, and the coarser fragments were deposited to form the gravel beds above described. After the Kansan ice had retreated beyond the limits of the drainage area tributary to this valley, when the stream had shrunk to the dimensions required to carry off the normal precipitation, and when the current was no longer loaded, erosion attacked the gravel beds and re-excavated a portion of the valley down to the level of the plain represented in profile at A, Figure 18.

The beds of gravel and sand are the only deposits seen in the county that can as yet be referred to the Buchanan interglacial stage, but the abandoned channel of Lime creek (Fig. 11) represents a piece of rock erosion accomplished during this interval. This channel is not wide when compared with the preglacial valley of the same stream, but, from the summits of the adjacent hills to the rocky floor that supports a

heavy bed of peaty humus and Iowan drift, its depth exceeds fifty feet. As pointed out in discussing the topography of the county, the time interval which the abandoned channel represents was probably long even as compared with all post-Iowan time.

IOWAN DRIFT.

Drift of the Iowan stage constitutes the surface materials over almost three-fourths of the county. This drift sheet varies very greatly in thickness, for there are areas in which it seems to be represented only by typical bowlders without an appreciable quantity of finer detritus; and there are other places where its thickness may exceed a score of feet. Where well developed it presents the usual characteristics of a yellow clay mixed with more or less of sand and gravel, with scarcely more signs of oxidation and ferrugination at the surface than at greater depths, its calcareous constituent unaffected by leaching, even at the grass roots, and bearing bowlders of undecayed, light-colored granites. The bowlders often attain enormous size. Figure 15 illustrates one of the great masses of granite plentifully sprinkled over the area occupied by Iowan drift. Much larger blocks, however, than the one illustrated are sometimes seen. One of these, composed chiefly of large reddish crystals of feldspar, protruded a foot or two above ground in Kirk's addition to Mason City. An effort was made to remove it by blasting it to pieces; but after taking it out to a depth of twelve feet, and finding its dimensions increasing all the way down, the effort was abandoned. When the work stopped the size of the exposed surface was eighteen feet in length by sixteen feet in width. The depth or thickness is unknown. A still larger bowlder of the same kind of granite is seen near the west line of the southwest quarter of section 7, Portland township. The dimensions above ground are twenty-five feet in length, twenty-three feet in width and eleven feet in height. A smaller mass of the same granitic species is only a few feet removed from the larger one, and it is possible that when they started on

their journey the two constituted but a single block. Bowlders varying in size from three to five, or even eight feet in diameter are very common.

The Iowan drift, in this region, seems to have been on the whole rather meager in amount, and it now forms a thin sheet of till conforming to the inequalities of the pre-Iowan surface. It is spread over the uplands and higher plains of the area in which it is distributed; it covers the beds of gravel at a lower level within the limits of the preglacial valleys; it descends upon the low plains adjacent to the streams in the relatively narrow valleys formed by interglacial erosion; and it partly fills the abandoned interglacial channel north of Mason City. At the Hackberry exposure of Lime Creek shales the Iowan drift, undisturbed since it was deposited, covers a low plain north of the stream; while south of the stream it is spread over a plain more than seventy feet higher, which plain begins at the summit of the Hackberry escarpment. In sections 16 and 17 of Lake township, in 24 of Mason, in 24 of Owen, and at other points in the county, this drift sheet rises from low plains or valleys to spread a thin mantle over preglacial ridges composed of Lime Creek shales.

The scantiness of the materials in the Iowan drift is well illustrated on the higher lands, in the area underlain by beds of the Lime Creek stage. The region south and west of Mason City is plentifully strewn with Iowan bowlders, but the drift is so thin that the soil through which the farmer drives his plow is in many places made up of decomposed shales of Devonian age. The same is true of the fields that extend south from the summit of the Hackberry exposure in section 35 of Portland township. The Iowan bowlders are imbedded in Lime Creek shales, and the ordinary clayey till seems to be almost entirely absent. About Rockwell the Owen beds of Lime Creek age protrude at intervals through the drift over areas of considerable extent, notwithstanding the fact that numerous bowlders clearly testify that the whole region was once overrun by Iowan glaciers. It is also true that in the

localities noted the materials of the drift sheets older than the Iowan are equally scanty.

WISCONSIN DRIFT.

There are at present no known deposits in Cerro Gordo county referable to the interglacial stage (Toronto?) between the Iowan and the Wisconsin. Deposits piled up by the Wisconsin ice sheet are, however, conspicuous features of the Pleistocene formations in the western townships of the county. The area has been described in connection with the subject of topography. The deposits themselves consist of the ordinary materials that elsewhere make up the Altamont moraine. Fine glacial clay predominates, but the clay contains some sand, a great many pebbles, and a less number of bowlders ranging from a few inches to a foot or two in diameter. The clay is a lighter yellow than that of the Iowan drift, and it contains a large amount of calcareous matter. The pebbles are fragments of crystalline rocks with which are mingled a very large proportion of pieces of limestone. In places the limestone fragments seem to predominate with respect to numbers, and many of them contain traces of fossils. The bowlders are, as a rule, smaller than those scattered over the Iowan area; they are darker in color, with a tendency to bluish shades; and a large proportion of them are intersected with seams and veins of trap. The Wisconsin drift, therefore, is readily distinguished from the Iowan by its paler, more calcareous clay, its great numbers of limestone pebbles, and its smaller, darker colored bowlders which often are weathered into very erratic shapes. The irregular weathering is due to the presence of intrusive veins which render certain parts of the individual bowlders harder and more resistant than the rest. Limestone pebbles, which are so common and characteristic in the Wisconsin drift are very rare in the Iowan.

The hills and knobs of drift constituting the Altamont moraine presented to the first settlers of the region the

appearance of being made up of gravel. The gravel was, however, limited, as tests have demonstrated, to a thin superficial layer. The whole body of Wisconsin drift is rich in pebbles. On the steep slopes of the morainic hills rain erosion, acting through many centuries, removed the finer glacial clays and sands from the surface stratum of drift; and the pebbles, too large to be moved, were left as a thin residual layer over the tops and sides of the irregular moranic bosses of drift.

Eskers and valley trains.—The hills and bosses that characterize the moraine become less pronounced in the southern and southwestern part of Grimes township. Indeed in the southwestern part of this township the hills fade into the level, characterless topography peculiar to the central areas of Wisconsin drift. In this level region, parts of which are still very marshy, are the initial branches of the south fork of Beaver Dam creek which, flowing southeast, finally emerges upon the area of Iowan drift. The valley of this creek seems to have been the chief outlet in Cerro Gordo county for the waters resulting from melting of the Wisconsin ice. Accordingly, near Thornton, about half a mile southwest of the village, there is a well defined esker in the form of a long ridge of gravel resting on Wisconsin drift. This gravel, as might be inferred from its origin, contains a large proportion of limestone pebbles. The ridge, which is three-fourths of a mile in length, trends a few degrees south of east. It is not quite parallel to the present drainage. The course of the glacial stream, to which it owes its origin, was determined by conditions affecting the margin of the Wisconsin ice, and not by the conditions that determined the position and course of the modern streams.

In the neighborhood of Thornton the streams flow over beds of the same kind of gravel found in the esker. A heavy accumulation occurs below the village near the point where two branches flow together. Trains of gravel follow the creek valley beyond the limit of the moraine, well out into the

region of Iowan drift. The last gravel beds of this age in Cerro Gordo county occur along the south line of section 36, Pleasant Valley township, where the stream passes into Franklin county.

POSTGLACIAL DEPOSITS.

More recent deposits of the Pleistocene period are found at a number of localities, particularly in the Altamont moraine. Peat has accumulated, and is still accumulating, in the kettle holes and undrained basins of the moranic belt. The peat bed marking the site of an old lake basin, already noted as one of the topographic features of section 24 of Union township, and adjacent sections, affords a typical illustration of such deposits. Near the southwest corner of section 34 of the same township, a basin of some extent, filled with peaty material mixed with rain wash from the surrounding hills, was dry enough for cultivation during the past season. The black, peaty soil, turned by the plow, abounds in shells of pond snails belonging to the genera, Physa, Limnæa and Planorbis, and a well dug at some distance from the margin of the basin reveals a thickness for the deposit of six or eight feet, and charged with shells of the same species throughout its entire extent. It is needless, however, to multiply examples. Peat beds, complete or in process of formation, occur in almost every quarter section of the broad belt covered by the moraine. They are particularly numerous in portions of Union and Grimes townships.

The beds of sand around the east end of Clear Lake are a product of forces that have been operating continuously since the retreat of the Wisconsin glaciers. The sand is not derived from decay of siliceous rocks in place, or in the immediate neighborhood, for no such rocks are found within some hundreds of miles of the lake. It must be regarded as the residuum left after removal of the finer silt from a large body of glacial till, waves and meteoric waters being the agents of such removal. The ridge of sand and gravel which has

converted a former part of the lake into a detached marsh west of the Assembly grounds, is a comparatively recent deposit due to expansion and shoreward creeping of lake ice during the many successive winters since the lake was born. After terrestial vegetation gained a foothold on the ice-heaved ridge, the further growth of the deposit may have been aided by the effect of winds, for drifting dust and sand would tend to lodge in every spot that afforded the requisite degree of shelter.

There are no bodies of alluvium worthy of record along any of the streams of Cerro Gordo county.

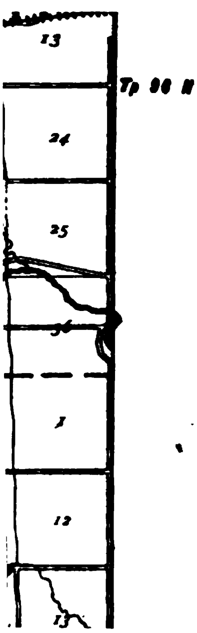
SOILS.

The soils of Cerro Gordo county are mostly of the drift type. In the area of Iowan drift, the land is comparatively level, and the soil is a deep black loam, rich in organic matter, and with sufficient admixture of sand to make it warm, mellow and easy of cultivation. A typically level stretch of farming land occurs in the southwest part of Falls and adjacent parts of Lime Creek and Portland townships. A farm embracing an entire section may have its surface so perfect a plane that every part of it may be viewed from some central point; and every square foot of such a farm may be cultivated. Notwithstanding the apparent level, there is no evidence that these lands suffer from lack of drainage. There is some slope to the surface, and the subsoil is so porous as readily to carry off any ordinary excess of storm waters. Similar level areas of exceptionally rich farming lands, susceptible of high cultivation with the least conceivable amount of labor, occur in Owen, Dougherty, Bath, Geneseo, Mount Vernon, Pleasant Valley and other townships. Adjacent to the streams there are lands with greater slopes, but nowhere in the Iowan drift region is there broken or hilly ground in the usual acceptation of the term. Along many of the streams the fields may be cultivated practically to the water's edge as is well illustrated in figures 12 and 13.

While the soils developed on the Iowan drift agree in certain particulars, there are yet varieties depending on the slope of the surface and the composition of the subsoil. Whenever the drift attains any considerable thickness, the soil is a black loam, usually somewhat sandy, rich in humus and containing a high percentage of calcium carbonate. On the highlands in the northwestern part of Lime Creek township, the subsoil is a moderately tenaceous drift clay, but the slopes of the surface insure perfect drainage. On the level space between the highlands and the modern valley of Lime creek the underlying Buchanan gravels furnish under drainage of the most perfect character. A somewhat anamolous type of soil for a glaciated area occurs in the regions of thin drift already noted, where the drift materials are represented chiefly by bowlders, and decomposed shales of Lime Creek age are stirred by the tools and processes of agriculture. The spaces over which the soils are simply decomposed shales, are, however, very small, for even where the shales are disturbed by cultivation, there was originally enough of drift to contribute a very important element to the soil.

In that portion of the county occupied by the Altamont moraine, the surface is generally broken and hilly as shown in figure 16. The low ground is mostly wet and marshy in seasons of average rainfall, but the hills are dry and easily cultivated. The soil is a rich loam, not so deep as on some portions of the Iowan area, but richer in calcium carbonate, and even better adapted to the cultivation of cereals. In a relatively small area around the margin of Clear Lake the soils are sandy; and in the extinct ponds and lakes whose basins have been filled or drained, a rich peaty soil, charged with shells of pond snails, is capable of supporting annually very heavy crops of grass.

There are no poor soils in the county. With the exception of the marshy spaces in the Altamont moraine, and a few low or otherwise unfavorably located spots in the region of the Iowan drift, every foot almost of the county can be



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cultivated. While the calcareous drift soils are especially well adapted to the cultivation of cereals and grasses, it is still true that there are no annual crops suited to this climate that may not be attempted with reasonable hopes of success.

Deformations.

There are many small folds and varying dips in the Cedar Valley limestones and in the overlying Lime Creek shales, but in no case is there evidence of deformation affecting the crust to any considerable depth. The folding of the Cedar Valley limestones is most frequently observed along the Shell Rock river between Plymouth and Nora Springs. Some of the more striking cases were noted in connection with the description of the geological structure of that region. The folds in question are not parallel one to the other, and cannot be said to constitute a system. It is not certain that they are due to crushing or lateral pressure. In some cases at least, and probably in all, the apparent folds and local examples of dip have been caused by intercalation of lentils, or by rapid local thinning or thickening of certain beds, as is well shown in the Portland section on Lime creek, figure 20.

The Lime Creek shales at Hackberry Grove show some undulations, with a slight general dip to the southwest; while, three miles west of Hackberry, in section 31 of Portland township, the southwesterly dip, as previously noticed, exceeds fifty feet to the mile. This dip is continued for only a short distance, however, for the Owen beds that appear at the surface about one mile south of the last named locality, are exposed at a number of points in the southeastern quarter of the county, and the altitude of the several outcrops indicates that the general inclination of the strata is very slight.

Unconformities.

There are some indications of unconformity between the Lime Creek shales and the underlying limestones, although it must be admitted that the evidence is not altogether conclusive.

For example, the limestones exposed along Lime creek, between Portland and Hackberry Grove, show no beds higher than No. 5 of the general section of the Cedar Valley stage (page 160), and the shales at Hackberry seem to rest on this member of the Cedar Valley section. Combining the exposures at Rockford and Nora Springs in Floyd county, there are forty-three feet of strata, Nos. 6 and 7, belonging to the Cedar Valley stage above No. 5 of the general section, and the Rockford exposures of the Lime Creek shales lie above No. 7. The strongest indications of unconformity are found at Mason City, and lie in the fact that the yellow and blue clays of Lime Creek age, worked by the Mason City Brick & Tile Co., have a thickness of forty feet as demonstrated by borings. This brings the bottom of the deposit nearly on a level with the water in Willow creek about half a mile north of the works. Along Willow creek, however, at the nearest point, there are ledges of limestone, and the stromatoporoid reef No. 4, of the general Cedar Valley section, lies at the summit of the exposure. There is no very marked dip to the beds in this locality, and so the base of the shales must rest on, or very near to, the upper surface of the Stromatopora reef. Near Mason City Junction, less than three-fourths of a mile east of the brick and tile works, beds belonging to No. 5 of the Cedar Valley section are exposed at an altitude nearly on a level with the upper surface of the shales in the clay pit. Along the abandoned channel of Lime creek, north of Mason City, the equivalents of beds 5, 6 and 7 of the general Cedar Valley section are developed above the stromatoporoid reef, and yet these beds all seem to be absent beneath the shales at the brick and tile works.

Two possibilities present themselves for consideration. *First*, the peculiar relations of the shales to the underlying limestones may indicate an emergence of the area, a period erosion, and subsequent subsidence between the Cedar Valley and Lime Creek stages, and so the phenomena may be due to true unconformity. *Second*, it is possible that there may have

been rapid local thinning out of the later beds of the Cedar Valley limestones in a manner illustrated by some of the beds in figure 20, and that there was no erosion interval between the two stages. The evidence at hand is not sufficient to warrant a statement as to which view is more probably correct.

The several Pleistocene deposits are unconformable on each other and on the underlying beds of sedimentary origin.

ECONOMIC PRODUCTS.

Building Stones.

Building stone is quarried at various points throughout the county. The principal quarries are in the Cedar Valley and Lime Creek stages of the Devonian. Some quarrying is also

FIG. [illegible]. Kuppinger quarry in northern part of Mason City, showing the regular bedding below the stromatoporoid reef. In the view a man is standing at the level of the reef.

done in the Kinderhook beds of the Carboniferous, within a few rods of the county line in Franklin county, but none was observed in beds of this age in Cerro Gordo. The quarries of greatest value are located near Mason City, and all of these work the zones of whitish or grayish limestone and the granular dolomite, below the stromatoporoid reef.

The Kuppinger quarry (Fig. 22) on the east side of Lime creek, in the northern part of Mason City, furnishes several hundred cords of good building stone annually. The section of this quarry has been already given. Beds 2 and 4 of the section are available for quarry purposes, but the stone from the dolomitic phase, No. 2, is much more desirable than that from the overlying limestones. The layers, as seen in Fig. 22, vary greatly in thickness and so afford a wide range of choice in this particular. The thicker layers furnish blocks suitable for heavy bridge piers, and the product of the thinner layers is adapted to lighter structures. A boiler and steam drill are the only labor-saving machines at present employed. The quarry is worked intermittently, and the market is local.

Belding Stone Co.—The quarries of the Belding Stone Co. are extensive openings in the bluffs facing Lime creek in the northwest quarter of section 27, Lime Creek township. No. 1 of the section of this quarry, page 150, is made up of eight layers of granular dolomite varying in color through shades of brown, blue and gray. The first layer is 12 inches thick and is used for rubble stone. Layers 2, 3, 7 and 8 are respectively 7, 6, 6 and 8 inches in thickness and are taken out in blocks suitable for walls laid in definite courses. No. 4, which is 4 inches thick, is quarried for large slabs used in street crossings; and Nos. 5 and 6, the first 13, and the second 11 inches thick, furnish material for heavy walls. Above the "Blue cap," No. 2 of the section, there are dolomitic beds, the first of which furnishes stone for bridge piers or other heavy structures. The second and third are sufficiently fine in texture to be used for dimension stone, being cut for caps, sills, water tables and other purposes for which cut stone may be employed. The whitish fine-grained limestone above the dolomite, Nos. 4 and 5 of the section, is used for a variety of purposes. The quarry is equipped with a steam drill and a number of derricks. Much of the product of this quarry is shipped abroad; a wagon haul of half a mile, however, is at

present necessary to reach a shipping point on the nearest railway, the Iowa Central.

Mason City Stone Co.—The Mason City Stone Co. has extensive quarries on the west side of Lime creek in the northwest quarter of section 34, Lime Creek township. The quality of the stone is in general the same as that at the quarries already described. The dolomitic phase has here a thickness of 19 feet, and the individual ledges vary from 4 to 22 inches in thickness. The dolomite is overlain by 12 feet of white or light grayish limestone. The quarry furnishes rubble, heavy footing stone, some dimension stone, stone for sidewalks or street crossings, and stone for range work. The stone for range work is easily shaped with the hammer. The quarries of this company have been worked for fifteen years. The Iowa Central railway has lately built a spur into the quarries, affording excellent facilities for loading and transportation. The product is marketed chiefly abroad, shipments being made for long distances north, south and west from Mason City, into territories that have no natural outcrops of indurated rocks, or none that furnish stone suitable for building purposes.

Mason City Quarry Co.—On the opposite side of Lime creek, and a little north of the quarries last described, the Mason City Quarry Co. operates two or three small quarries. The beds quarried are the same as those already noted. Teams and wagons afford the only present means for transporting the product. The market is local, and the work in the quarries intermittent. There are derricks for handling the heavier blocks, but no other machinery apart from the ordinary hand drills and other tools in universal use in quarrying.

OTHER QUARRIES IN CEDAR VALLEY LIMESTONE.

There are a number of small quarries worked at various points in the bluffs of Lime creek, Willow creek and Calmus creek. In the aggregate these produce annually a large

amount of stone. Among these may be mentioned the Peterson quarry in the southeast quarter of section 27, Lime Creek township; the quarries on Willow creek, on land of O. T. Denison, east of the crossing of the Iowa Central railway; the quarries on Calmus creek, in the northern part of Mason City; the quarry at Portland and others southeast of Portland, in Portland township, and a number of small quarries in the western part of Lime Creek and the eastern part of Lincoln townships. Mention must also be made of several quarries that afford excellent stone, in the bluffs of the abandoned channel of Lime creek in the northwest quarter of section 34, Lime Creek township. There are also quarries near Shell Rock Falls, and at points between Shell Rock Falls and Plymouth, in Falls township.

Quarries in the Owen beds.—The Owen beds of the Lime Creek shales are quarried at the typical exposure in the southwest quarter of section 31, Portland township; in the southwest quarter of section 5 of Owen township; in section 12 of Dougherty, and in sections 3, 4, 10, 26 and 36 of Geneseo. The stone from this horizon is usually a rather soft yellow earthy dolomite, and not of very high grade. Some portions of the quarries near Rockwell show firmer and more calcareous layers, and some exposures in section 35 of Geneseo township are composed of beds of moderately pure granular limestone. The stone from quarries of the Owen beds is much inferior to that from the Cedar Valley limestone near Mason City, and while these quarries are of very great local value, they are not likely to become commercially important.

Value of quarry products.—It is difficult to collect data respecting the annual value of the building stone produced in Cerro Gordo county. The year 1896 was one of unusual depression in the building stone industry, but the best information obtainable indicates that the value of the stone quarried in the county during this year does not fall very much short of $50,000. In years of prosperity the demand was three times as great as during 1896. Were an equivalent

value in gold, silver or coal produced, the importance of the geological products of the county would receive readier recognition.

Future of the stone industry.—The quarry industry of Cerro Gordo county is yet in its infancy. In the first place there are numerous vertical cliffs, as at Parker's mill (Fig. 19), that form natural quarry faces, and are so situated with respect to stripping and facilities for disposing of refuse, as practically to require no labor for their development. At all these exposures the admirable quality of the stone with respect to its power of resisting the weather, is well demonstrated. In the second place, Mason City is situated at the border of an enormous quarryless area whose supplies of building stone must all be imported. No situation could be better chosen for commanding the markets of the great plains stretching away for hundreds of miles to the northwest, west and southwest. Here is an area growing annually in wealth and population, but an area in which the indurated rocks are deeply buried under a thick mantle of drift. The facility with which stone may be quarried along Lime creek and its tributaries, coupled with the excellence of the product, should, therefore, enable Mason City to get an ever increasing share of the building stone trade in the vast stoneless empire to which this city is practically the gateway.

Lime.

The Cedar Valley stage is capable of furnishing indefinite supplies of lime-burning rock, some of which produces a very high grade of lime. At present, however, lime is made on a commercial scale at but one point in the county, namely, at the lime-kilns of A. T. Lein and brother, in Mason City. The limestone is obtained from a quarry nearly one-tenth of a mile in length, worked in the bluff overlooking Lime creek. The part worked exposes the following section.

		FEET.
4.	Indefinitely stratified portion of the Stromatopora reef, with many laminar stromatoporoids	3
3.	Unstratified part of the reef with spheroidal stromatoporoids	5
2.	White or grayish, fine-grained limestone	15
1.	Granular dolomite	4

Below No. 1, down to the level of the stream, there are ten or fifteen feet unexposed, but judging from neighboring outcrops the beds in this part of the bluff are probably dolomite resembling No. 1 in quality.

Tramways and small cars afford means for transporting the quarried rock to the kiln. The cars are carried to the top of the kiln, the kiln being charged from above. Coal is used for fuel, and the burning is completed in forty-eight hours after the process is fairly started. It is estimated that three tons of coal make 150 barrels of lime. The kiln is known as the Champion draw kiln and was designed by Lein Brothers. The amount of the product varies from year to year according to the demand, but the number of bushels made annually mounts up into the thousands. The value of the output adds a very important sum to the total value of the products manufactured from the geological resources of the county. A large amount of the lime made by A. T. Lein & Brother is shipped to the quarryless region of deep drift west of Mason City. During the working season from six to eight men are constantly employed. The greater part of the lime manufactured at Mason City has been made from Nos. 2, 3 and 4 of the section at the limekiln. No. 2 especially produces a fine white lime that is held in much favor by many workmen for the reason, among others, that it slacks quickly and may be got ready for use in a short time. It is true, however, that lime made from the dolomitic phase, No. 1, if properly treated will be found much superior to that from either No. 2, 3 or 4. It takes longer to slack the more highly magnesian lime, and it should lie in the mortar bed for a greater length of time, but the superior results will more than repay the additional

trouble. For shipping purposes the lime from the dolomite has the great advantage of keeping for a long time without becoming air slacked, and if Mason City is to command the lime trade of the vast area that is hers by right of geographical position, attention should be given to the manufacture of lime from the dolomitized beds below No. 2. This lime will, without suffering deterioration, bear transportation for long distances, and may be kept in stock by dealers much longer than that from the purer limestone. Its property of setting harder, and its much greater power of resisting the chemical action of air and water which causes mortar to crumble and wash out of the joints in exposed portions of walls should commend the dolomitic lime at home as well as abroad.

Clays.

The blue and yellow, non-fossiliferous clays at the base of the Lime Creek shales are widely distributed in Cerro Gordo county and furnish inexhaustible amounts of material for use in the manufacture of clay goods of a great variety of kinds. For some purposes, as the manufacture of common structural brick, certain parts of the Iowa drift clays comparatively free from pebbles, will be found available. The drift clays of the Wisconsin stage contain so many limestone pebbles as to render them unfit for use in the manufacture of any clay products.

Mason City Brick and Tile Co.—At present clay goods are made at only one point in the county. The Mason City Brick and Tile Co. have an extensive plant (Fig. 23) in the southwestern part of Mason City. The clay used comes from the unfossiliferous portion of the Lime Creek formation. In the clay pit, which is just north of the factory, the beds exposed embrace twelve feet of blue shales overlain by twelve feet of yellow shales, with twelve to fifteen feet of blue shales known to exist below the bottom of the pit. The plant embraces the main factory building; steam heated drying sheds; an office building; six round, down-draft kilns; two

up-draft kilns; a Sioux City Corliss engine of 125 horse power; two eighty horse power boilers; a Madden & Co. machine with a capacity of 25,000 bricks daily; and the necessary hoists, tail

FIG. 23. Works of the Mason City Brick and Tile Co.

ropes, tramways, cars, pallets, etc., for handling the ware in the various stages of manufacture. The product of the factory includes.

1. End cut structural brick.
2. Hollow brick of the following dimensions:
   (a) 8x8x12 inches.
   (b) 4x8x12 inches.
   (c) 4x4x12 inches.
   (d) 4x8x10 inches.
   (e) 4x4x10 inches.
   (f) 8x8x8 inches.
   (g) 4x8x8 inches.
   (h) 4x4x8 inches.
   (i) 4x4x4 inches.
   (k) 2½x4x8 inches.
3. Agricultural drain tile three and one-half to twelve inches in diameter.
4. Sidewalk tile 2x8x8 inches.
5. Window sills and caps.

The clay burns to a light red color. The ware is very hard, ringing sharply under a gentle tap of the hammer, and is so compact as to be practically non-absorbent of water. Small crystals of selenite are diffused through the clay and cause a slight deposit of chalky looking powder on the surface of the ware in the process of the burning. For most of the product this in unobjectionable, but wherever it is desired to prevent its appearance, as in the case of face brick, it can be easily remedied by mixing a small amount of carbonate of baryta with the raw clay. An analysis of the blue clay in the lower part of the pit was made by Prof. G. E. Patrick, with the following results.

	PER CENT.
Hygroscopic water (expelled at 100° C.)	.85
Combined water (expelled by ignition)	3.74
Carbonic acid, CO_2	4.80
Silica, SiO_2	54.64
Alumina, Al_2O_3	14.62
Iron oxide (calculated as Fe_2O_3)	5.69
Manganese oxide (calculated as MnO)	.76
Lime, CaO	5.16
Magnesia, MgO	2.90
Soda, Na_2O	1.12
Potash, K_2O	4 77
Total	99.05
Error in analysis	.95
Total	100.00

The factory of this company is operated continuously throughout the year; twenty-seven men are employed, and the value of the annual output exceeds $30,000. The area in which the product of the factory finds a market has a radius of about 200 miles.

Nelson brickyard.—Some years ago a brick yard was operated about a mile north of Mason City. The clay used is a modified drift only about eight inches thick. This clay was tempered in the ordinary pug-mill, and the brick were made by hand. Temporary kilns were used for burning. No work has been done here, however, in recent years, and with

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deposits. Most of the springs seem to have their origin in the porous beds of the Pleistocene, and flow takes place wherever these water-bearing beds, under proper conditions, come to the surface. Owing to the imperfect surface drainage of the morainic area in the western part of the county, the pebbly clays of Wisconsin drift are saturated with water, and abundant supplies are obtained from very shallow wells. Flowing wells frequently result from penetrating these clays to a moderate depth; and on the somewhat level plain into which the morainic knobs and ridges fade in the southwestern part of Grimes township, flowing wells are somewhat common. Clear Lake is probably fed almost exclusively by the underground streams of this morainic belt, and the underground supply is doubtless largely due to the fact that the surface drainage is as yet clogged, imperfect, undeveloped. Any causes that tend to facilitate the evaporation or the flow of water from the surface of the Wisconsin drift area and its marginal moraines, will diminish the volume of water in the lakes of the north-central part of the state.

MASON CITY DEEP WELL.

Water is found at varying depths in the indurated rocks below the Pleistocene beds. The most important supply from this source at present is that from the deep well at Mason City. The section of this well, copied from Norton's report*, is as follows.

		THICKNESS.	DEPTH.	ELEVATION A. T.
12.	Humus and drift	28	28	1,100
11.	Devonian and Silurian	276	304	824
10.	Maquoketa	57	361	767
9.	Galena-Trenton	405	766	362
8.	Saint Peter	105	871	257
7.	Upper Oneota	113	984	144
6.	New Richmond	50	1,034	94
5.	Lower Oneota	145	1,179	-51
4.	Saint Croix (Jordan)	70	1,249	-121
3.	Saint Croix (Saint Lawrence)	174	1,423	-295
2.	Saint Croix (Basal sandstone)	45	1,468	-340
1.	Algonkian (?) penetrated	5	1,473	-245

*Iowa Geol. Surv., vol. VI. p. 195. Des Moines, 1897.

The main water supply in this well comes from Nos. 2–4, which collectively represent the Saint Croix sandstone. This sandstone is the source of the water in nearly all the deep wells of Iowa. No. 8 of the well section is very properly identified by Norton with the Saint Peter sandstone. This second sandstone marks one of the most persistent and most easily recognized of the geological horizons, and it extends with uniform characteristics underneath a large portion of the

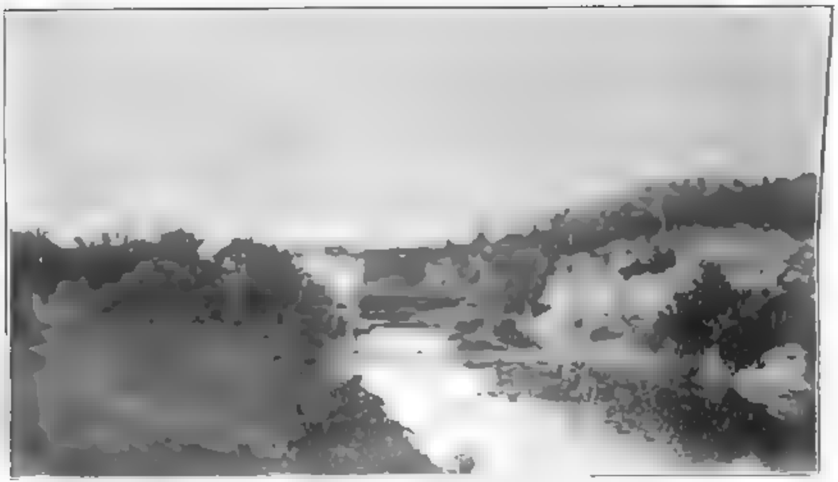

FIG. 24. Kuppinger's mill in the north part of Mason City—a typical mill site on Lime creek

state. The water in the Mason City well is excellent in quality, and the supply is ample for the present needs of the city.

Water Powers.

Out of a great many possibilities afforded by the streams of the county, water powers have been improved and utilized at only a few points. On Lime creek the Lincoln mills, in section 15 of Lincoln township, have a head of eight feet; the Kuppinger mill (Fig. 24), in the northern part of Mason City, has about the same head, and the Portland mill, at Portland, has also a fall of eight feet. The old Parker's mill at Mason City is located on Willow creek. On the Shell Rock river

there are mills at Plymouth, and there is now an unused, but formerly well developed water power at Shell Rock Falls.

ACKNOWLEDGMENTS.

This report would be incomplete if it did not acknowledge the indebtedness of the author to the many interested friends of the Survey, who courteously aided in many ways the collection of the data on which the report is based. All information that could possibly be of service was cheerfully given, and some gave time and labor in the furtherance of the objects for which the Survey was conducted. Especial acknowledgments are due to O. T. Denison, superintendent of the Mason City Brick and Tile Co. Mr. Denison's thorough acquaintance with the county, coupled with the habit of close and accurate observation, made it possible for him to give such information and render such assistance as greatly reduced the time required to find and visit the points of most importance. Acknowledgments are also due to E. P. De Graw, of Lincoln Mills, and to Ade Randall, S. C. Belding, A. T. Lein and others interested in the stone and lime industries of the county. Valuable assistance in the field work was received from Frederick Larrabee, Harold M. McLaughlin and Hugh H. Shepard, and in a part of the work done on Pleistocene geology the assistance of Dr. S. W. Beyer was a highly appreciated advantage. To these, and to the many others not specifically mentioned the author extends sincere thanks.

GEOLOGY OF MARSHALL COUNTY.

BY

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CONTENTS.

INTRODUCTION.

LOCATION AND AREA.

Marshall is one of the middle tier of counties and lies between Tama and Story counties on the east and west respectively. The Iowa river makes a bold bend southward nearly to the center of the county, where it turns abruptly eastward, cleverly detaching the northeast quarter. As in the case of most of the inland counties of Iowa, Marshall comprises a rectangular area of approximately five hundred and seventy-six (576) square miles and considerably more than a third of a million acres.

PREVIOUS GEOLOGICAL WORK.

Considering the great value of the natural resources of Marshall county and the varied and abundant fauna entombed in the rocks, the literature concerning the geology of the region is extremely meager.

David Dale Owen* in his "Reconnaissance of the Carboniferous Rocks of Southern and Western Iowa," was the first geologist to visit the county in an official capacity. He traversed the county in the vicinity of the Iowa river, and incidentally called attention to the more salient geological features. J. D. Whitney† in treating of the geology of Marshall and adjoining counties records the occurrence of coal in Bangor township, and briefly describes a section exposed on Timber creek near the old road leading from Marietta to Indiantown, in which he remarks the close resemblance of the rocks to the lower Burlington limestone as exposed at its typical locality.

More than a score of years later White‡ described the exposures near Le Grand and definitely refers the formation to the Kinderhook stage of the Carboniferous system. Certain quarry products are also described, and in the same

* Geological Surv. Wisconsin, Iowa and Minnesota, p. 101-102. 1852.

† Geology of Iowa, vol. I, pp. 267-9. Albany, 1858.

‡ Geology of Iowa, vol. I, pp. 197-198. Vol. II, pp. 260, 312-314 and 316. Des Moines, 1870.

report Prof. Rush Emery* reports an analysis of "Iowa marble," from the Le Grand quarries.

The crinoidal remains so abundant in certain layers at Quarry and Le Grand have received the attention of the late Charles Wachsmuth† and his co-laborer, Frank Springer, of Burlington, and others.

PHYSIOGRAPHY.

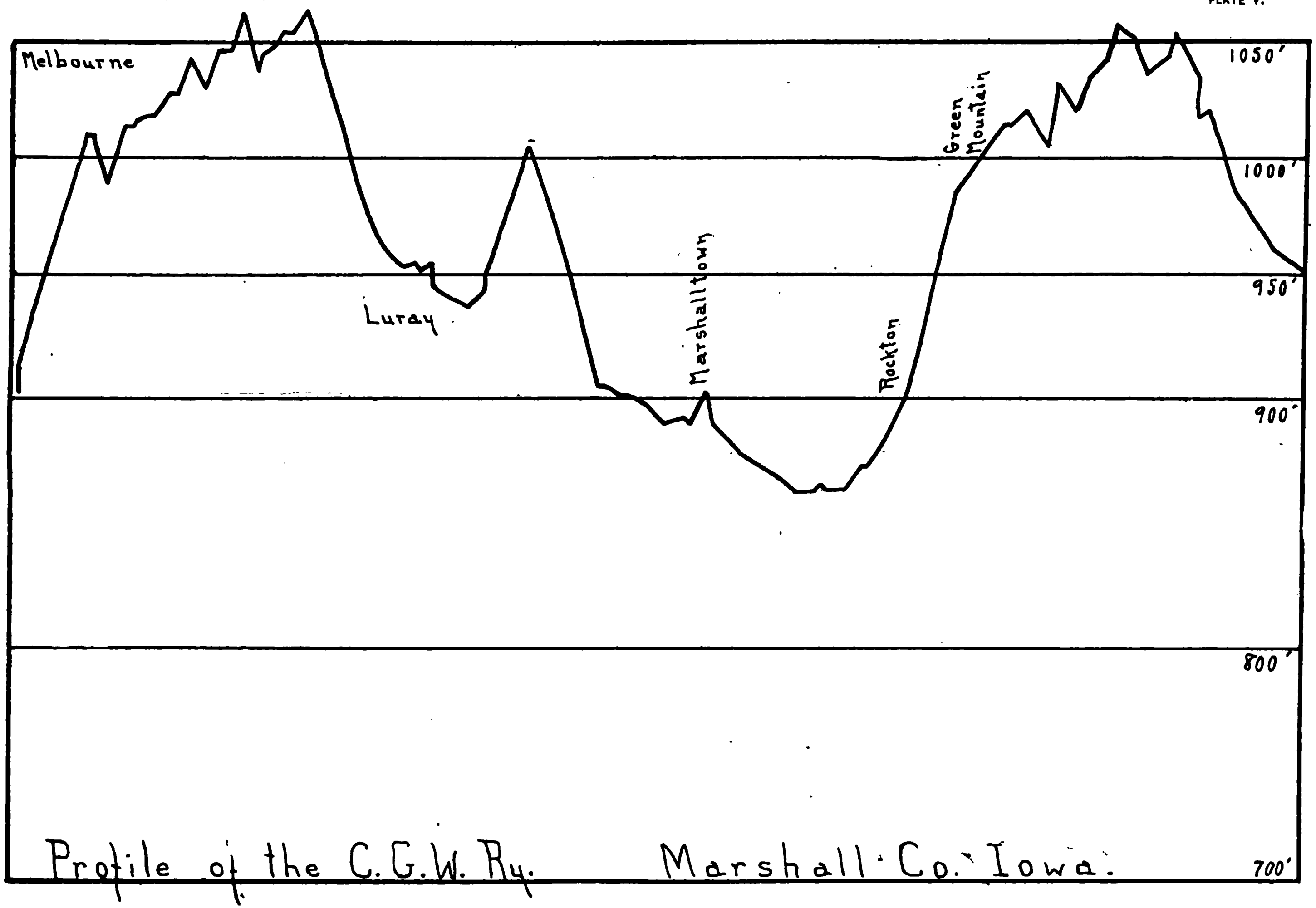
TOPOGRAPHY.

The topographic features of the county are varied. In order better to understand the more general configuration, conceive a more or less regular surface very gently inclined to the southeast. Let there be a slight depression in the position of the Iowa river, flanked on either side with parallel ridges, the crest on one side bisecting Vienna township diagonally, while a line passing through State Center, Van Cleve and Laurel marks approximately the position of the other. Spread over the surface a material which responds readily to water action, but holds with equal fidelity the vigorous carving of the spring freshet and the most delicate tracery of the summer shower; given these conditions, time and the erosive agents are the only requisites to account for the general physiography of the region.

The principal water courses have wrought out well-marked flood plains bordered by the usually gently rising uplands, all of which attest topographic maturity. The vertical interval between the lowlands and the adjoining uplands varies from 50 to 100 feet, but the altitude gradually increases towards the divides which attain an elevation of more than 200 feet above the water level in the Iowa river. Plate v shows the cross-section of the general plain. The most vigorous land forms occur in the marginal areas which intervene between the upland plain and the flood plains of the greater streams. These areas, with the flood plain, originally supported a luxuriant forest growth, but have in large part been dismantled.

* Ibid vol. II, p. 347.

† Geological Surv. Illinois, vol. VIII, pp. 157-205, and pls. xv-xvii, 1890.


Melbourne
Luray
Marshalltown
Rockton
Green Mountain
1050'
1000'
950'
900'
800'
700'
Profile of the C.G.W. Ry. Marshall Co. Iowa.

While the whole county is heavily drift-laden, yet the territory readily resolves itself into three distinctive topographic areas which are coincident in a general way with the areas occupied by the Wisconsin, Iowan and Kansan drift sheets, and will be designated by the terms, drift, drift-plain and drift-loess types respectively. The first type is represented by a wedge-shaped area on the western margin of the county, whose apex is approximately at the southwest corner while its base spans little more than three miles on the north line. The characteristic features of the region are the prevalence of depressions, sloughs and "kettle holes" and eminences with kame and drumloid affinities. Drainage is imperfect and this, when taken in conjunction with the unique surface features, is indicative of topographic youth.

The second comprises an area of scarcely more than fifty square miles in the northeast corner of the county. Although the Iowan till sheet probably extended over a greater area in the county it was not competent to control the configuration of the region to the extreme limits of its attenuated margin. Away from the larger streams this territory is characterized by a monotonous, plane surface interrupted by occasional gentle swells, and as a rule it is moderately well drained, while oftentimes prairie sloughs are much in evidence. This triangular area is a fragment of the great drift-plain which extends northward far into Minnesota and comprises an area of more than seven thousand square miles in Iowa.

The drift-loess type constitutes more than four-fifths of the surface of the county. The topographic features are purely erosional and the contours are strengthened by the loess top-dressing. The upland is dissected by a plexus of small streams which gives the surface a graceful, billowy aspect, very pleasing to the eye. Sharp V-shaped valleys and convex hills are the rule in the broken areas and bear silent testimony to the instability of the surface configuration. The larger streams meander through broad valleys which are almost destitute of salient topographic features. The divides are better defined

than is usual in this type of topography. The head branches of opposing drainage systems often interlock, so sharply is the territory contested.

TABLE OF ELEVATIONS.

The following table of altitudes is compiled from the profiles of the different railroads which traverse the county.

STATION.	Altitude.	AUTHORITY.
Albion	937	I. C. Ry.
Dillon	975	I. C. Ry.
Divide, Iowa and Cedar rivers	1054	C. G. W. Ry.
Divide, Iowa river and Linn creek	952	I. C. Ry.
Divide, Iowa and Skunk rivers	1116	C. & N.-W. Ry.
Dunbar	878	C., M. & St. P. Ry.
Ferguson	909	C., M. & St. P. Ry.
Gilman	1090	I. C. Ry.
Gladbrook	954	C. G. W. Ry.
Green Mountain	1000	C. G. W. Ry.
Haverhill	1023	C., M. & St. P. Ry.
Iowa river, Chicago Great Western crossing	865	C. G. W. Ry.
Iowa river, county line	926	I. C. Ry.
Iowa river, Iowa Central crossing, south of Albion	895	I. C. Ry.
Lamoille	940	C. & N.-W. Ry.
Le Grande	940	C. & N.-W. Ry.
Linn creek, Great Western crossing southwest of of Marshalltown	905	C. G. W. Ry.
Linn creek, Great Western crossing east of Marshalltown	875	C. G. W. Ry.
Laurel	1040	I. C. Ry.
Liscomb	950	C. G. W. Ry.
Duray	885	C. & N.-W. Ry.
Marshalltown	890	I. C. Ry.
Marshalltown	900	C G. W. Ry.
Malta	1062	I. C. Ry.
Melbourne	1045	C. G. W. Ry.
Melbourne crossing, Chicago, Milwaukee & St. Paul railway	1060 1033	C. G. W. Ry. C., M. & St. P. Ry.
Nicholson creek	896	C. G. W. Ry.
Pickering	987 1025	C., M. & St. P. Ry. I. C. Ry.
Quarry	885	C. & N.-W. Ry.
Rhodes	1015	C., M. & St P. Ry.
Rockton	880	C. G. W. Ry.
State Center	1073	C. & N.-W. Ry.
State Center Junction	1051	C., M. & St. P. Ry.
Timber creek, Iowa Central crossing	874	I. C. Ry.
Timber creek, Chicago & North-Western crossing	855	C. & N.-W. Ry.
Van Cleve	1054	I. C. Ry.

DRAINAGE.

Marshall county is well watered and for the most part is also well drained. The annual rainfall averages about thirty inches per annum, of which less than one-third is gathered up into the streams and carried to the gulf. Five-sixths of the annual "run-off" finds a convenient outlet through the Iowa and its tributaries, while small triangular areas in the southwest and northeast corners contribute their surplus waters to representatives of the Skunk and Cedar river systems respectively.

Iowa river system.—The Iowa river is the master stream in the system and in large measure establishes the grade for its numerous tributaries. It meanders through a broad alluvial

FIG 25. Le Grand gorge.

valley which averages from one to two miles in width. The river crosses the Kinderhook escarpment at two points; near its entrance into and exit from the county. At the latter place the river flows through a gorge scarcely a quarter of a mile in width. The present stream occupies a channel but little below the general level of the bottom land and extensive reaches of territory are subject to periodic inundation. Deserted channels are everywhere in evidence, and northwest of Marshalltown sand flats are common features of the

flood plain. The Iowa river has long since passed its adolescent stage, has reached maturity and is now approaching old age. The stream is not corrading its channel at any place. Excavations for bridge piers and abutments show that the country rock lies ten to fifteen feet below the present stream bed. At the Marshalltown waterworks there is an apparent exception to this. The river impinges strongly upon the south bank, and the country rock is close to the surface in the bed of the stream. Excavations for the water galleries on the north flank of the flood plain reveal the fact that the old rock bottom slopes away from the present position of the channel.

The Iowa drainage system is of the asymmetric type with the greater tributaries coming from south and west as are the Skunk and Des Moines rivers in central Iowa. Rock, Burnett and Asher creeks are the principal tributaries received from the north; while Timber, Linn, Minerva and Honey creeks are the more important branches received from the south and west. All of these have much the same general characters as does the greater stream. All are long in proportion to their volume, and all are characterized by drainage basins which are relatively narrow in proportion to their length.

The tributaries from the north are relatively of much less importance than those from the south. They have narrow flood plains or none at all, and have deposited but little alluvium save in their lower courses. Asher creek is the largest and drains an area of about fifty-four square miles. Each has cut through the drift at certain points exposing the upper member of the Kinderhook beds.

Timber creek, which enters the Iowa from the south near Quarry, collects the water from an area of 130 square miles. It comprises three principal branches which are named according to their geographic positions—North, Middle and South Timber creeks. North Timber flows almost due east, and is much the longest member, while the south branch

flows north and comprises the greatest drainage basin. All have narrow, but well marked flood plains, which follow well up far towards their sources.

The drainage basin of Linn creek is the narrowest in proportion to length of any in the county. The proportion of length to breadth is about six to one, and the valley comprises an area of about seventy square miles. Its course is almost exactly parallel to the North Timber creek, but it has not progressed as far in valley forming as the latter. The most rugged topography in the county is found in the territory traversed by Linn and the Timber creeks.

Minerva creek has its source in Hardin and Story counties. It pursues a tortuous course in a southeasterly to easterly direction, and enters the Iowa a little north of west of the town of Albion. The head waters of this stream arise in the area of the Wisconsin drift, and drain more than two-thirds of the region covered by this till sheet in the county. The lower course of the Minerva has a flood plain which, considering the volume of the stream, is quite broad. It has numerous small branches; but where its tributaries leave the Wisconsin, the valleys are sharply constricted. In the upper reaches little or no alluvium has been deposited, and there is a dearth of minor streamlets.

Honey creek has done an immense amount of work in the way of valley cutting, which as in the case of the Minerva, is out of all proportion to the size of the present stream. It has cut through the drift and exposes the coal measure shales and Lower Carboniferous limestone near Bangor. Mud creek, a prairie stream through the greater part of its course, and without the usual accompaniment of alluvial bottom land, is the principal tributary of Honey creek—the two streams joining just as they enter the flood plain of the Iowa.

Age of the Iowa system.—The Iowa system bears the impress of age; of advanced maturity. The original topography of the county did not depart far, perhaps, from that of a plain and the present configuration is due almost wholly to erosive

forces. The limiting divides average about two hundred feet higher than the Iowa flood plain. The down cutting alone would require thousands of years, while the true enormity of the task and the vast lapse of time can only be realized when it is considered that the river valley averages from one to two miles in width. Sufficient data are not at hand definitely to determine the age of the system; but, considering the broad valleys of the Iowa and its principal tributaries, and the fact that the Kansan drift, apparently undisturbed, follows down the hillsides at least to the level of the flood plain, much lower than the outcroppings of the country rock as in the vicinity of Quarry, Le Grand and Timber creeks, it may tentatively be stated that the system, in part at least, is pre-glacial. The profoundly glaciated surface exposures at Le Grand, Timber creek and Linn creek, all located on the south flank of the present stream valleys, may also be admitted as evidence of preglacial depressions in the direction from which the ice came. It seems probable that the Iowa river, from Le Grand to the mouth of Honey creek at least, the lower courses of Timber, Minerva, Honey and perhaps Linn creeks have sought out and partially reopened their old channels. The minor streams and the upper courses of the larger tributaries are doubtless usually superimposed upon the glacial deposits and are independent of preglacial configuration. In terms of stream development the Iowa has passed its zenith and old age is slowly but surely coming on unless stream action be reinvigorated by deformation and uplift of the region. The surface inequalities have long since reached their maximum and the hills are slowly melting away to fill the valleys. The melting snows and summer showers humble the one that they may contribute to the upbuilding of the other. Man himself is a potent factor in this leveling process. The old settler can well remember the time when the waters of our streams were untarnished at the spring freshets or summer floods save by the crystal amber from our virgin prairies. At the present time after

such periods the streams flow liquid mud. The prairie grasses and forest trees wére conservators of moisture and firmly held the soil in place. The processes of agriculture in subduing the prairies and denuding the forest areas have increased the "run-off" and rendered the soil easily eroded. Culture has stimulated the small streamlets to a new cycle of cutting, as is evidenced by gullied fields and roadsides. Some of these cuttings are more than ten feet in depth.

Skunk river system.—A triangular area in the southwestern part of the county drains through tributaries of the Skunk river. The hypotenuse of the triangle is approximately followed by the State Center branch of the Iowa Central railway and its area is about ninety square miles. The principal representatives of the system are Clear creek, North Skunk river and Snipe creek. All flow approximately at right angles to the general slope of the county. Clear creek and the Skunk river are wooded streams, while the Snipe is timberless. Clear creek has more deeply incised the region through which it flows than its co-workers, but none of them have done much in the way of valley formation. The valley of Snipe creek is boggy in character and suggests the fitness of its name.

The Cedar river system is feebly represented in the northeast corner of the county. The drainage from about two square miles takes this route to the "father of waters."

TERRACES.

Stream terraces are doubtfully represented in Marshall county. Timber creek, on sections 8 and 17 in Le Grand township, is accompanied by a low shelf fifteen to twenty feet above the flood plain in the streams. This bench can be identified at several other points in the various branches of this stream and is the nearest approach to a terrace found in the region.

Minerva creek, in Liberty township, sections 22 and 27, is apparently terraced. The bench is eight to ten feet above

the flood plain and is composed of Wisconsin drift. Here is the semblance of an old valley partially filled by the Wisconsin ice, and the present narrow flood plain represents the cutting since the retreat of the last ice sheet.

STRATIGRAPHY.

General Relations of Strata.

The geologic history of Marshall county is recorded in strata which belong to two distinct series separated by an enormous time break. A feeble realization of the immensity of the interval which elapsed after the completion of the first chapter and before the commencement of the last, can only be gained when we catch occasional glimpses of profoundly eroded areas and base-leveled plains.

The underlying stratified rocks belong to the Carboniferous system. Lying unconformably upon these is a thick mantle of Pleistocene deposits which effectually conceal the older rocks, save along some of the larger streams. The formations present are tabulated below.

CLASSIFICATION OF FORMATIONS.

GROUP.	SYSTEM.	SERIES.	STAGE.	SUB-STAGE.
Cenozoic.	Pleistocene.	Recent.		Alluvial.
		Glacial.	Wisconsin.	Fourth till.
			Iowan.	Loess. Third till.
			Buchanan.	
			Kansan.	Second till.
			Aftonian.	Albion gravels.
			Sub-Aftonian?	First till.

CLESSIFICATION OF FORMATIONS—*Continued.*

GROUP.	SYSTEM.	SERIES.	STAGE.	SUB-STAGE.
Paleozoic.	Carboniferous.	Upper, or Pennsylvanian.	Des Moines.	
		Lower, or Mississippian.	St. Louis.	
			Augusta.	
			Kinderhook.	Marshallt'wn shales. Le Grand beds. Hannibal shales?

The Lower Carboniferous forms an unbroken platform upon which all of the later deposits rest. The coal measures partially overlap this formation and comprise about one-half the area of the county. While the present surface slopes gently to the southeast, the underlying stratified rocks are inclined to the southwest or at right-angles to the general surface inclination. The average dip of the strata is about fifteen feet per mile in the eastern portion of the county, but the beds become almost perfectly flat to the westward.

The deeper strata have only been explored at one point,—Marshalltown. The following is the sequence of strata passed through in sinking the deep well near the city water works. The record* is based on sample drillings saved by Dr. W. S. McBride of Marshalltown.

	THICKNESS.	DEPTH.
13. Limestone, light gray in fine sand, with many angular fragments of limpid quartz at 68 feet		70
12. Limestone, light yellow, compact, earthy luster, three samples	45	115
11. Limestone, brown, crystalline, cherty, at 115	30	145

* Prof. W. H. Norton kindly loaned to the writer his manuscript on the Marshalltown well, and from it the recorded descriptions and interpretations are taken almost verbatim.

		THICKNESS.	DEPTH.
10.	Shale, soft, light green, calcareous	175	320
9.	Limestone (?) no samples	145	465
8.	Limestone, hard, brown; gray and brown crystalline, rapid effervescence, samples at 465 and 560	155	620
7.	Dolomite, yellow, gypseous and cherty	55	675
6.	Limestone, magnesian, brown, samples at 675, 690 and 700, cherty at 675	95	770
5.	Dolomite, cherty and gypseous; drillings consist mostly of white and translucent chert	30	800
4.	Chert, white and translucent; samples at 800	75 (?)	875
3.	Limestone, rapid effervescence; drillings consist almost wholly of chert with some gypsum, samples at 875 and 900	15	915
2.	Dolomite, white in powder, with some chert and gypsum	10	925
1.	Shale, blue and green-gray, non-calcareous in samples, 925 to bottom of boring at	95	1,020

SUMMARY.

NO.	FORMATION.	THICKNESS —FEET.	DEPTH —FEET.
11, 12, 13.	Mississippian (Kinderhook limestone)	145	145
10.	Kinderhook (Shales)	175	320
8, 9.	Devonian	300	620
2–7.	Silurian	305	925
1.	Maquoketa penetrated	95	1,020

The sub-crystalline gray limestone and the buff magnesian limestone which attain such prominence in the exposures near Le Grand can be recognized as Nos. 13 and 10 respectively in the above section; but no trace of the equally prominent oolite and blue sandstone is to be found in the drillings. The whole assemblage of limestones above the green shale undoubtedly belong to the Kinderhook, while the taxonomic relations of the shale itself are not so clear. For the present, perhaps, it is best to follow Professor Norton and provisionally treat the formation as belonging to the Kinderhook, although latter developments may show it to be in part Devonian. Mr. C. N. Hutson, well driller, reports 260 feet of shale penetrated in sinking a well at the glucose works in the

south part of town. This heavy bed of shale does not outcrop any place in the county, nor, so far as known, any place in central Iowa, but its stratigraphic position seems to be the same as the thick shales encountered in the deep wells at Ottumwa and Sigourney* and the blue shale which outcrops at the base of the bluffs along the Mississippi river at Burington.†

The section ends in the Maquoketa shales which forms a well defined terrain throughout central Iowa, which may be taken as a standard of reference to determine the general dip of the deeper strata for this region. At Ackley and Cedar Rapids‡ this formation is reached at about 400 and 300 feet respectively above sea level. At Marshalltown the top of the shale is fifty feet below tide, while at Ames the shale rises more than 100 feet above sea level.

Standard Sections.

The best exposures are found in the vicinity of Quarry and Le Grand along the Iowa river. The Le Grand Quarry Co. in the development of their property have laid open to inspection sections which aggregate nearly two miles in length and nearly one hundred feet in vertical thickness. Other sections of less importance may be observed where the smaller streams cross the Kinderhook escarpment, as, for example, on Timber, Linn and Honey creeks, and near the towns of Albion and Bangor.

The following sequence of beds may be observed at the East quarries near Le Grand.

SECTION I.

	FEET.	INCHES.
18. Loess, interstratified sands and silts below	16	
17. Bowlder clay oxidized a deep brown and containing bowlders much decayed	5-10	
16. Limestone, sub-crystalline, pebbly	3	
15. Oölite, fine-grained, with many brecciated grains	4	

* Geology of Iowa, vol. III, pp. 203-205, pl. xviii, 1893.
† Geology of Iowa, vol. I, pp. 192-193, 1870.
‡ Geology of Iowa, Vol. III, pp. 189-192 and 195-197. 1893.

		Feet.	Inches.
14.	Limestone, gray, slightly oölitic	2	6
13.	Limestone, gray above, and yellow below	2	
12.	Limestone, buff, magnesian, rather heavily bedded, bisected by chert band about four feet from the base	9	
11.	Limestone, mixed gray, blue and buff, breaks very irregularly ("Brindle" of the quarrymen)	3	6
10.	Chert		4
9.	Limestone, soft, yellow, in thin layers and arenaceous; earthy in places	2	6
8.	Chert		4
7.	Limestone, blue, variegated to yellow-brown	6	
6.	Chert		3
5.	Fossil-breccia with lenses of crystal calcite	1	
4.	Limestone, buff, magnesian, fine even texture and massive; cherty, concretions scattered promiscuously throughout. One quitepersistent band of chert about four feet from the base	12	
3.	Limestone, blue, variegated to brown, hard, conchoidal fracture, and in heavy layers	3	6
2.	Oölite, in layers, 14, 12, 8, 9, 6, 36, 26, 24 and 42 inches in thickness	15	
1.	Sandstone, fine-grained, blue, calciferous, in part shaly (exposed)	10	

No. 1 in the above section is exposed in the quarry north of the river and appears at no other point in the county. The dip is about four degrees to the southwest, and this, with the slope of the stream, soon carries the beds below the surface. Near Indiantown, in Tama county, the base of the oolite lies more than twenty feet above the water level, while at the west quarry both oölite and sandstone have passed below the bed of the river, and No. 16 has a thickness of about twelve feet. The upper layers at Le Grand probably form the base of the section at Marshalltown. At the latter place the following series, which consist principally of shales, may be seen near the Woodbury flouring mills.

SECTION II.

		FEET.
7.	Loess, sandy	2
6.	Clays, and sands with some bowlders, variegated; highly oxidized in streaks	6
5.	Calcareous, pebbly material containing large chert concretions; the original limestone structure is almost obliterated	4
4.	Shale, ash-blue, graduating downward into arenaceous beds	6
3.	Limestone, arenaceous, impure	2
2.	Shale, dark blue, slightly sandy and concretionary and slacks rapidly on exposure; many of the fragments spotted with white flocculent material	4
1.	Limestone, brown, sub-crystalline, base	

All of the beds are more or less irregular and are cut out eastward. A continuation of the above exposure, in the form of a low ridge, runs southwestward from the mill, departing somewhat from the river, and perhaps outlining the position of an old escarpment. The ridge continues for nearly a mile, gradually wanes and passes under the drift bluff at the Soldiers' home.

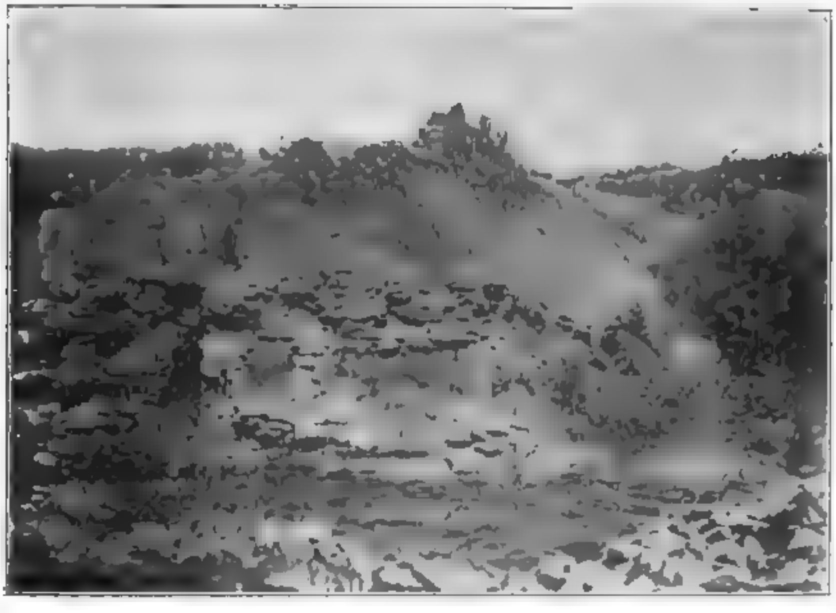


FIG. 28. The upper Le Grand beds as exposed at Rockton.

At Rockton the upper portion of section 1 is duplicated almost perfectly.

SECTION III. ROCKTON.

		FEET.
6.	Loess and soil	1-3
5.	Till, yellow (Iowan)	2-4
4.	Till, reddish-brown, sometimes blue below (Kansan)	0-3
3.	Limestone, brown, sub-crystalline, rubbly	3-5
2.	Limestone, oölitic, heavy bedded	5
1.	Limestone, gray-brown, beds thinner and slightly argillaceous	2

Two drift sheets are represented here. Numerous granitic

FIG. 27. The Le Grand beds as exposed on Timber creek at the I. C. Ry. crossing. The loess maintains a vertical scarp, while the Kansan till slopes.

bowlders are present in the base of the Iowan in places. Numbers 1, 2 and 3 in the above section may be referred to Nos. 14, 15 and 16 respectively in section 1.

At the point where the Iowa Central railway crosses Timber creek a slightly different facies of the Kinderhook beds may be observed.

SECTION IV. TIMBER CREEK.

		FEET.
8.	Loess, sandy, below	10
7.	Bowlder clay (Kansan)	6
6.	Limestone, brown, sub-crystalline, thinly bedded, and rubbly above, heavier below	8
5.	Limestone, yellow, brittle, with occasional small caverns decorated with concretionary calcite	1½
4.	Limestone, blue, hard, brittle	2
3.	Oolite in three layers, 8, 22 and 6 inches respectively	3
2.	Limestone, gray-brown, with layers of blue, sub-crystalline limestone interbedded	6
1.	Limestone, gray-blue, close textured, soft when first exposed, weathered portion, yellow; layers vary from 6 to 18 inches, very evenly bedded, magnesian	12

The oölite in the Timber creek section is undoubtedly the equivalent of the oölite exposed at Rockton and the "upper oölite" of section 1, numbers 1–6, in the above section find their counterparts in 12–16 in the Le Grand section, with the possible exception of number 5, which was not recognized farther north. The differences in physical properties and coloration are largely, if not wholly, due to the differences in weathering. The Timber creek beds are better protected than those at Le Grand. The prevailing colors of the unweathered product are shades of blue and gray, while tones of yellow and buff are brought about through the action of weathering agencies. The hardness of the Timber creek stone increases on exposure.

SECTION V.

(Tp. 83 N., R. XVIII W., Sec. 8, Sw. qr., Se. ¼.)

		FEET.
3.	Loess	1–3
2.	Till, oxidized throughout a deep brown	2–5
1.	Sandstone, reddish-brown in heavy beds, certain layers show oblique bedding, exposed	12

The sandstone exhibits a conglomeratic facies in part. Well polished grains of sand and gravel are held in a matrix

of ferric oxide. Some of the iron oxide is often in the form of small nodules which frequently are hollow and possess the concentric structure peculiar to concretions. Throughout the beds are the impressions of the trunks and branches of trees which have retained their woody structure in a remarkable degree, although their original organic substance has been entirely replaced by mineral matter. In some instances a pulverulent ash surrounded by a highly ferruginated shield are the only remains. In one case, a central core of very

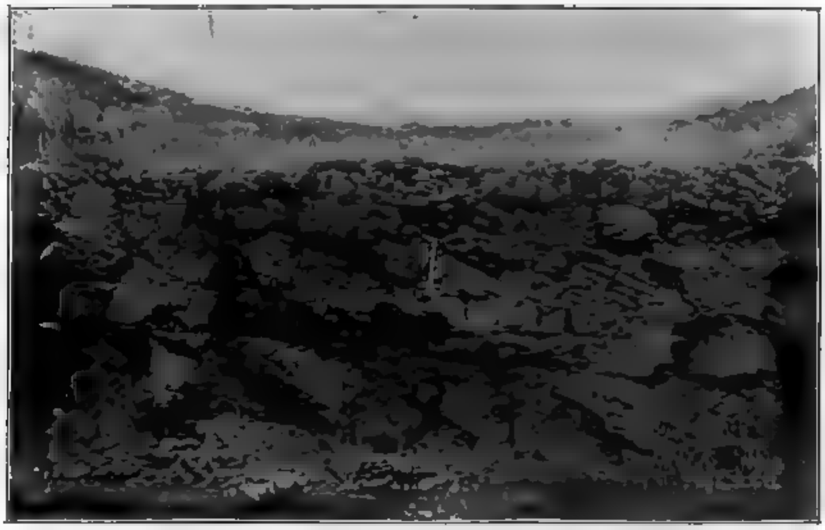


FIG. 28. Carboniferous sandstone in Timber Creek township, Sec. 8, Sw. qr., Se. ¼.

hard material, almost quartzitic, was noted; around this a zone of wood fiber, and surrounding all the concentric ferruginous shield. All of the stems were in a recumbent position. No faunal remains could be found.

Geological Formations.

CARBONIFEROUS SYSTEM.

With a few unimportant exceptions, the stratified rocks in the western half of the county are entirely concealed by the Pleistocene deposits. Rocks of the Lower Carboniferous age

have been exposed northwest of Liscomb near the Iowa river, and also east of Bangor on Honey creek. Coal measure outcroppings appear on Honey creek and along the Iowa river between Bangor and Albion.

MISSISSIPPIAN SERIES.

Owen, in his description of the Carboniferous rocks of the Iowa river definitely referred the rocks exposed near Le Grand to the Subcarboniferous. He says in part: "It was not, however, until reaching the northwest corner of Tama county that rocks of the Subcarboniferous era were seen unequivocally in place. Here, on the left bank of the Iowa, * * * both oölitic and encrinital beds of Carboniferous limestone protrude; and where the river crosses the corner of Marshall county the characteristic fossil, *Pentremites pyriformis* was found, along with *Terebratula plano-sulcata*, *Spirifer striatus* and *Productus semireticulatus*." He also calls attention to the change in the surface configuration, the beginning of a more vigorous topography, and the increased growth of timber, both of which, perhaps, are more or less independent of the country rock, but mark the transition of the drift plain into the loess-drift topography.

J. D. Whitney describes a section on Timber creek and disposes of the exposures near Indiantown and Le Grand as follows: "About one-half mile northwest of the town [Indiantown] a thin bedded, brittle limestone with a pinkish tinge is seen cropping out along the summits of the low ridges, * * * succeeded, in a descending order, by thin layers of white crystalline limestone filled with fragments of crinoidal columns. These layers contain intercalated masses of chert, and some of the beds are oölitic in structure, the whole assemblage closely resembling the outcrop of the Burlington member of the Carboniferous limestone as seen at that place. * * * In some loose masses of oölitic limestones * * * there were found specimens of Spirifer (?) ———, and an Avicula resembling *A. marionensis* Shumard."

* Geology of Iowa, Pt. 1, pp. 267-8, 1858.

White, in his discussion of the "Carboniferous System,"* describes the section at Indiantown, which is practically the same as the exposures at Le Grand, as consisting of.

		FEET.
3.	Soft irregularly bedded magnesian limestone passing up into purer and more regularly bedded limestone	40
2.	Light gray, oölitic limestone in heavy layers	15
1.	Yellowish, shaly, fine-grained sandstone	20

Continuing he says: "The characteristic fossils of the Kinderhook formation prevail throughout the whole series of beds found at Indiantown, even including the whole forty feet of No. 3. Although the upper part of No. 3 presents the lithological appearance of some parts of the Burlington limestone, yet its distinctive paleontological characters are wanting or feebly shown. The whole is therefore referred to the epoch of the Kinderhook beds, especially since the line of demarkation between the rocks of this epoch and those of the Burlington limestone is nowhere definite."

Wachsmuth and Springer,† in their chapter on the crinoids and blastoids from Le Grand, Iowa, accept White's reference of Nos. 1 and 2 in the above section, but observe that the upper part of No. 3, of the Le Grand and Indiantown sections is, in their opinion, very probably the representative in part of the Lower Burlington limestone. A specimen of *Actinocrinus proboscidialis* which is one of the most characteristic species of the Lower Burlington, is mentioned as having been found in the upper layers; and these authors suggest that the upward limit of the Kinderhook is coincident with upper limits of the magnesian limestone.

To summarize briefly, Owen and Whitney considered the Le Grand beds to be the equivalents of the encrinital formations,—the Lower Burlington limestone at Burlington, the correlation being based almost wholly on lithological resemblances. White definitely assigns the assemblage to the Kinderhook as defined by Meek and Worthen, basing his opin-

* Geology Iowa, vol. I, pp. 195-7, 1870.
† Geol. Sur. Illinois, vol. VIII, pp. 155-208, 1890.

ion on paleontologic evidence; while Wachsmuth and Springer, in their study of the echinodermatous remains in the beds, confirm White's reference, in the main, but suggest the probability of certain of the upper layers belonging to the Lower Burlington.

The present investigation affords no reason to dissent from Professor White's reference. Professor Calvin has kindly identified a series of fossils collected at Le Grand, Timber creek and Rockton, some of which were taken from the extreme uppermost strata, and he finds them to possess distinctively Kinderhook characters.

KINDERHOOK.

The Kinderhook beds in Marshall county attain a maximum thickness of nearly 150 feet.* The entire sequence may be

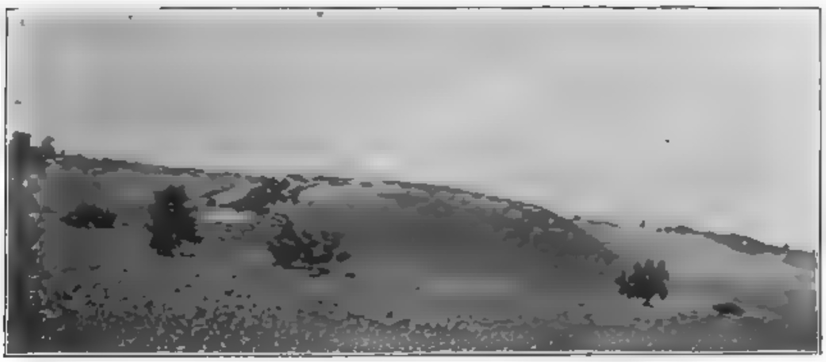


FIG. 29. Kinderhook outlier. Marshall-Tama line on the Iowa river.

observed by visiting two sections. The greater portion of the section is exposed at Le Grand, while the uppermost beds may be seen at Marshalltown.

THE LE GRAND BEDS.

The Le Grand beds comprise a total thickness of about 135 feet, as evidenced by the deep wells in Marshalltown which penetrate these deposits. Scarcely 100 feet of strata are

* The above estimate does not include the 175 feet of shale exhibited in the Marshalltown deep well, which is doubtfully referred to the Kinderhook

exposed at the Le Grand when all of the outcrops are combined. Although the Le Grand beds constitute a strati-

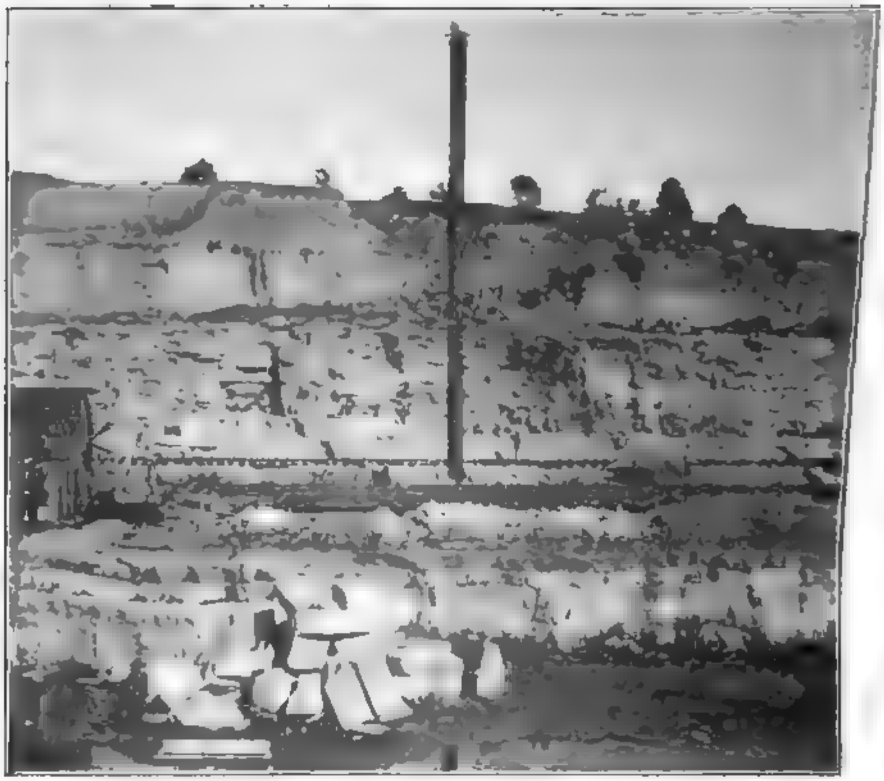


FIG. 30. Le Grand beds as exposed at southwest quarry, Le Grand. (1) Oölite, (2) Chert beds, (3) Crinoid zone, (4) Ice-planed surface of the brown and gray subcrystalline limestone.

graphic unit, for convenience of discussion they may be subdivided lithologically into four fairly well worked terrains, as follows:

		FEET.
4.	Brown and gray subcrystalline limestone	30
3.	Buff magnesian limestone, cherty below	35
2.	Gray-white oölite	15
1.	Argillaceous, blue sandstone	20

The lowest member consists of a very soft, fine-grained bluish white sandstone, slightly argillaceous above and heavy bedded below. The sandstone is exposed only at the north-

east quarry within the limits of the county. At Indiantown, about two miles east of Le Grand, the sandstone is very friable and takes on a yellowish tone due to weathering. Casts of fossils were observed.

The oölitic member is in very heavy layers and is evenly bedded. It is of a gray-white color and is only exposed in the two east quarries at Le Grand. This terrain is fossiliferous throughout. The principal forms recognized were:

Entolium circulus Shumard.

Straparollus latus Hall.

Productus sp. (?) and fish spines and plates.

The third member comprises about thirty-five feet of homogeneous, fine-grained, buff, magnesian limestone, which, lithologically and faunally, may be subdivided into three zones.

		FEET.
3.	Heavy bedded magnesian limestone; barren zone	12
2.	Arenaceous marly layers; Encrinital zone	4
1.	Chert beds { Barren zone, 12 feet; Chonetes zone, 8 feet }	20

The chert beds consist of irregularly bedded magnesian limestone, much divided by quite persistent chert bands and cherty concretions scattered promiscuously throughout the deposit. This division is almost devoid of organic remains, save in the chert bands and associated layers near the base, which are closely set with Chonetes. *Productus arcuatus* Hall, was found along with the Chonetes. The chert beds are separated from the oölite by a variegated, heavily bedded, subcrystalline brown and blue limestone, whose most characteristic organic remains are fish spines. A large spine of Ctenacanthus, similar to *C. furcicarinatus* of Newberry, was found in this layer.

The middle layers are thinly bedded and of a marly arenaceous character, forming a fit receptacle for the abundant crinoidal fauna which they contain. More than nine-tenths of the Echinodermatous remains found at this locality were confined to these shaly, marly layers, which have an aggregate

thickness of less than four feet, and may fittingly be designated the "Encrinital zone."

Wachsmuth and Springer,* the eminent authorities on the Paleozoic Pelmatozoa, have described the following species of crinoids and blastoids from the Le Grand beds:

Athinocrinus ornatissinus W. & Sp.
Athinocrinus nodobrochiatus W. & Sp.
Athinocrinus arnoldi W. & Sp.
Megistocrinus nobilis W. & Sp.
Megistocrinus parvus W. & Sp.
Batocrinus macbridei W. & Sp.
Dorycrinus immaturus W. & Sp.
Dorycrinus radiatus W. & Sp.
Dorycrinus parvibasis W. & Sp.
Rhodocrinus kirbyi W. & Sp.
Rhodocrinus nanus Meek & Worthen.
Rhodocrinus watersianus W. & Sp.
Platycrinus symmetricus W. & Sp.
Platycrinus planus Owen & Shummard?
Dichocrinus inornatus W. & Sp.
Graphiocrinus longicirrifer W. & Sp.
Scaphiocrinus elegantulus W. & Sp.
Scaphiocrinus globosus W. & Sp.
Taxocrinus fletcheri Worthen.
Taxocrinus intermedius W. & Sp.
Orophocrinus conicus W. & Sp.
Orophocrinus fusiforms W. & Sp.

In describing the mode of occurrence and former habitat and state of preservation of this most interesting assemblage of organisms, the above authors write as follows: "It appears that the Le Grand crinoids were deposited in very quiet waters, and in many cases were imbedded just as they died. They occur in nests and colonies, and genera and species are commingled indiscriminately. It is, therefore, a curious fact that while the specimens of some species are of

* Geological Surv. Illinois, vol. VIII, pp. 157-205. 1890.

pure calcareous composition and of a light color, those of others, under precisely similar conditions, lying side by side with them, sometimes even with stems and arms intertwined, are harder and of a very dark brownish-gray color. * * * The stems are short, * * * and is worthy of note that in all our perfect specimens from Le Grand * * * taper to a fine point, giving off rootlets in all directions, and there is in no instance any indication of an attachment by the column to a solid substance * * *. Taking everything into consideration, it seems to us the numerous small rootlets, spreading in all directions lead to the conclusion that those crinoids, with but few exceptions, either lived upon a soft, oozy bottom, in which they were rooted like plants, or that the rootlets served as an anchor by which the animal attached itself to foreign bodies."

The brachiopodous fauna is represented as follows in this zone:

Spirifer biplicatus Hall.
Orthothetes crenistria Phillips.
Rhynchonella sp (?).
Spirifer sp (?).

The upper layers of the magnesian limestone consist of heavy beds two to four feet in thickness and rather evenly bedded. A chert band bisects the division near its middle, but otherwise it is quite free from siliceous matter. Fossils are rare.

The magnesian limestone is exposed in its entirety in the two east quarries at Le Grand. At the west quarry the upper two divisions only are exposed. At the Timber creek quarry the top of the upper division is but little above water and this division alone has been explored. These are the only localities where this formation appears in the county.

The uppermost Le Grand beds comprise a composite series consisting in the main of gray or brown, subcrystalline limestone, and gray oölite. This oölitic layer is near the base and is composed of four feet of typical oölite resting on two

feet and a half of shell breccia with an oölitic facies. The limestone above the oölite is hard, thinly bedded and rubbly in character. Occasionally chert bands are present, but they are less abundant than in the magnesian layers. The whole assemblage is highly fossiliferous throughout, the chief forms being:

Spirifer subrotundus Hall.
Spirifer extenuatus (?) Hall.
Spirifer biplicatus Hall.
Orthothetes crenistria Phillips.
Rhynchonella, *sp* (?).
Terebratula, *sp* (?).

Fish remains and crinoid stems are often present in abundance, but *Actinocrinus proboscidialis* Hall, is the only crinoid calyx described from these beds.

The upper division is present wherever the Le Grand beds have been recognized within the limits of the county. It plays an important role in the Kinderhook escarpment, whose position is approximately marked out by a line passing through the Le Grand, Rockton, Corrick and Liscomb quarries. The valleys of the streams which have cut into the country rock are constricted where they cross this line. This is best seen in the valley of the Iowa itself. (See Pleistocene map.) The most extreme westward outcrops may be noted on the Iowa river north of the Soldiers' Home, on North Timber creek, and on South Timber creek near Ferguson. At the last three places only the thin bedded, brown, subcrystalline limestone may be seen.

MARSHALLTOWN SHALES.

About fifteen feet of argillo-calcareous beds are exposed near the Marshalltown Flouring Mills. They consist of ashblue to deep blue shales interbedded with argillaceous limestones. Chert nodules are present in the upper calcareous layers. After diligent search no trace of organic remains could be found. In the absence of distinctive characters these

beds may be referred conditionally to the Kinderhook. Concretions similar to those mentioned above are found along the river westward to the great bend, but not in place.

AUGUSTA.

Although Hall considers the Le Grand beds to be the equivalent of the Lower Burlington and Wachsmuth and Springer have suggested the probable equivalency of the brown subcrystalline layers at Le Grand with the same formation, yet the matter now stands pretty much as it did more than a quarter of a century ago, when White failed to find sufficient reason for the differentiation of the Lower Carboniferous in Marshall county. With the data in hand at the present time the Augusta cannot be recognized definitely within the confines of the county.

SAINT LOUIS.

In Bangor township in the Sw. qr., Sw. ¼ of Sec. 16, a heavily bedded, close-textured limestone is quarried in the bottom of Honey creek. The rock is of a dark, ash-gray color and contains some small, cherty concretions. Iron pyrites occur in bands and sheets in certain layers. The rock breaks with an uneven or hackley fracture, and some blocks give a metallic chink when struck with a hammer. No fossils could be found. Lithologically, these beds have a very close resemblance to the lithographic facies of the Saint Louis limestone as exhibited at the quarries north of Ames on the Skunk river, and at Webster City on the Boone river. The area is mapped as Kinderhook, but probably should be referred to the Saint Louis. Coal measures overlie these beds at this point.

DES MOINES STAGE.

The coal measures (Des Moines) overlap the Lower Carboniferous formation in an irregular manner and occupy nearly one-half the superficial area of the county. The general trend of the overlapping edge of the formation is east of

south, extending from the northeast corner of Bangor township to the southwest corner of Green Castle township. There are reëntrant angles where the principal streams make their exit from the measures, with the exception of Middle Timber creek; there being an extension at this point. A prolongation of the coal measures extends westward into Iowa and Liscomb townships and may have been at one time continuous with the outlier in Vienna and Taylor townships, which marks the extreme eastward limit of the Des Moines in the county. Outcroppings of the coal measures are few and unimportant, so perfect is their concealment by the glacial debris. At certain points along the Iowa river northwest of Albion on Honey creek, a thin coal seam along with carbonaceous shale may be noted. In Timber Creek township a heavily bedded, red sandstone appears along a tributary of Linn creek, near the Chicago Great Western railway on sections 8 and 9. Outcrops of the same beds may be observed near the water level on the Middle Timber in sections 26 and 34. Away from the margin there are no exposures of the Des Moines in the region. The deeper wells in the vicinity of State Center undoubtedly penetrate the coal measures, which consist largely of shales. In sinking a well for Emanuel Hepner, Tp. 85, N., R. XVII W., Sec. 30, Se. qr., Ne. ¼, the following sequence of strata was reported.

	FEET.	INCHES.
Loess and drift	120	
Sandy, shelly rock, greenish yellow	2	
Coal		6-8
Red sandstone, soft	16	
Argillaceous limestone, very hard	1	
Argillaceous shale, light, ash-color	13	
Coal, carbonaceous shale and fire clay	6	
Hard, gray limestone (penetrated)	10	

Other wells in the vicinity are reported to exhibit a similar sequence. The Hepner well seems to be near the center of the outlier and hence the maximum thickness of the measures in this region may be taken as approximately forty feet. The Des Moines is doubtless much thicker in the western portion

of the county, but at present no well authenticated records are at hand.

Here, as elsewhere in Iowa, the Des Moines stage of the Upper Carboniferous consists essentially of shales and sandstones, with occasional layers of argillaceous limestones and seams of coal, all of which are interbedded in an intricate manner. The shales predominate in Marshall county and vary structurally from massive structureless clays through clayey shales to fissile shales; texturally form the purest shales through arenaceous shales to argillaceous sandstones. Colors are equally variable from the gray-white fire clays to the jet-black carbonaceous shales.

The prevailing sandstones are in shades of red, but in other regions, where better exposed, they are found to be equally as variable in physical properties as are the shales.

So far as at present known the argillaceous limestones and coal seams are sparingly developed in this territory.

PLEISTOCENE.

With a few unimportant exceptions where the larger streams have succeeded in cutting through and exposing the older formations, the Pleistocene deposits form a continuous mantle over the entire county. They are composed essentially of bowlder clays, sands, gravels and silts, often interbedded and intermingled in a most complex manner. Bowlders are not uncommon attendants to this most heterogeneous assemblage. The average thickness of the glacial debris on the uplands in this region, is upwards of 100 feet, and the present surface features are sculptured almost wholly in this material. At certain points in the county much greater depths are attained. In Eden Tp. on the northwest quarter of section 8, 190 feet was reported; Jefferson Tp., Sw. qr. of Sec. 22, 220 feet; Marietta Tp., Sw. qr. of Sec. 25, 212 feet; Liscomb Tp., Nw. qr., Sec. 22, 260 feet; Taylor Tp., Se. qr., of Sec. 1, 300 feet, and on the Sw. qr., 400 feet of drift was penetrated. In the latter township there seems to be a rock-

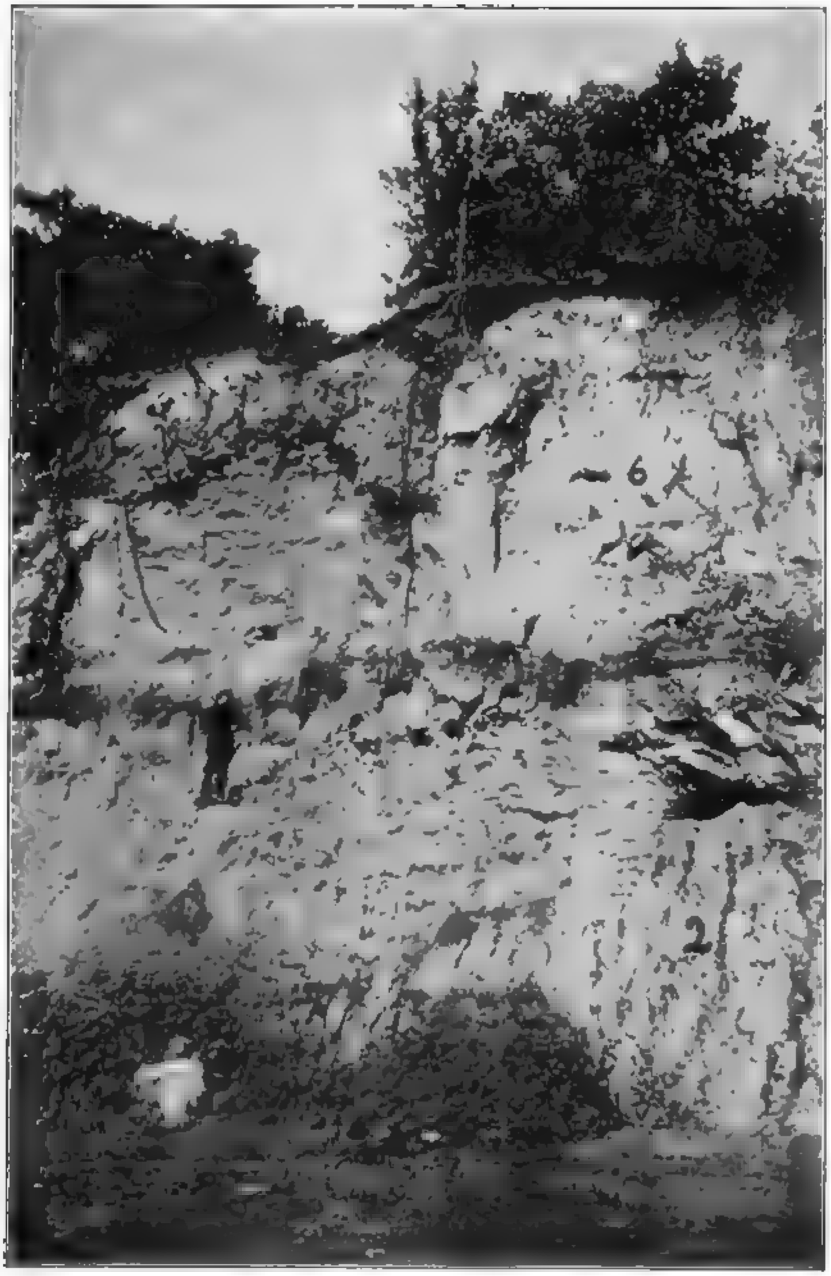
bound gorge trending northeast-southwest, bisecting sections 1 and 11, and more than a half mile in width. The southern wall of the gorge is apparently very abrupt, while the north wall rises gradually. The rock rises to seventy or eighty feet of the surface within half a mile southeast of the line of the gorge. Northward the rock is reached 190 and 180 feet below the surface on the Sw. and Nw. qrs. of section 2, respectively. The inequality of the slopes of this buried channel is analogous to that of the great majority of the Iowa streams of the present day. The south flank is almost universally the more abrupt.*

Although there are occasional hints of preglacial channels and depressions, none can be mapped definitely, and the general testimony of the drift wells is that the preglacial topography was milder than that of the present time. The type of topographic maturity. the pure plain, is suggested.

Marshall county has been subjected to at least three and perhaps four distinct ice invasions, separated by intervals of vigorous erosion and surface corrugation, or surface silting. The first two ice sheets were followed by gravel trains, while the last two were succeeded by intervals of surface silting and alluvium forming, respectively. The sequence of events may be described briefly in chronological order, and the corresponding deposits arranged stratigraphically as follows.

8.	Deglaciation and erosion	Recent (Alluvium in part.)
7.	Glaciation (western margin of county)	Wisconsin till.
6.	Deglaciation and surface silting	Loess.
5.	Glaciation (northeast corner)	Iowan till.
4.	Deglaciation and vigorous erosion	Buchanan gravels.
3.	Glaciation (general)	Kansan till.
2.	Deglaciation and erosion	Aftonian gravels.
1.	Glaciation	Sub-Aftonian till.

* The writer is indebted to Mr. Harry Weatherby for the records in Taylor township. The data is based on drillers' notes or derived from a personal interviews with the respective land-owners. Such evidence must be taken with a grain of allowance. The Kinderhook shales lie scarcely 100 feet below the general rock surface and might easily be mistaken for drift clays.



DRIFT SECTION AT ALBION.

SUB-AFTONIAN.

No till sheet below the Kansan has certainly been identified in this region. At the Albion mill, about ten miles northwest of Marshalltown, the following sequence of deposits may be observed, the basal members of which are pre-Kansan, and may be the equivalent of the sub-Aftonian.

ALBION SECTION.

		FEET.
6.	Loess, stratified sand and silt below	20
5.	Yellow till, apparantly wanting in places and often represented by characteristic bowlders only. (Iowan)	0–1½
4.	Gravel, bowlders four or five inches in diameter present, granitic members often much decayed; limestone pebbles common; bowlders of Kansan adorned with pebbles noted. (Buchanan)	2
3.	Till, upper portion oxidized a deep reddish brown, the lower portion unoxidized and gray-blue in color; jointed structures prominent throughout. (Kansan)	5
2.	Sand and gravel, stratified, coarser below; oxidized in streaks and bands approximately parallel to bedding planes. (Aftonian)	10
1.	Blue till* (Sub-Aftonian)	10

At the well put down in section 7, in Warren township, for Wm. M. Wallace, the drillers' record is as follows:

	FEET.
Yellow clay (loess, Iowan and oxidized portion of Kansan)	30
Blue clay (Kansan)	40
Sand and gravel (Aftonian?)	30
Blue clay (Sub-Aftonian?)	50

The above records at least suggest the presence of the pre-Kansan till sheet, but additional data are necessary before more explicit statements can be made concerning its characteristics and distribution.

AFTONIAN.

At the base of the Albion section ten feet of stratified sand and gravels may be observed. These beds were laid down,

* Not exposed, but R. W. Sheets reports ten feet of bowlder clay penetrated in sinking the abutments for the bridge.

in large part, through the agency of running water. Many of the pebbles and small bowlders bear polished, striated or facetted surfaces, yet the granitic members are oftentimes in an advanced stage of decay. The relation of this deposit to the Kansan is unquestionable, because till of the Kansan age rests immediately upon these beds. Gravels similarly related to the Kansan have been reported from various parts of the county, and the maximum thickness attained is about thirty feet.

The presence of a well marked terrane consisting of sands and of gravels, many of the pebbles and small bowlders of which bear the unmistakable imprints of glaciation, almost necessitate a preëxistant glacier and its universal product, the till sheet. *A priori*, this fact in itself would be sufficient reason for suspecting the presence of pre-Kansan glaciation (sub-Aftonian drift sheet).

KANSAN.

The Kansan ice covered the entire area under consideration and extended far southwestward into Missouri and Kansas, receiving its name from the latter state. As a till producer this great ice sheet is without a rival, and the elements of the present topographic features are boldly outlined in the till of this sheet.

The Kansan drift is composed essentially of bowlder clays containing pockets of sand and gravel and occasional bowlders of moderate size. The coloration is almost wholly due to the state of oxidation, and the formation may be divided arbitrarily into an upper oxidized portion and a lower unoxidized portion. The oxidized zone varies in color from a bright yellow to a deep reddish brown, while the unoxidized portion assumes some shade of blue, and constitutes the blue clay, hard pan, etc., of drillers. The degree of leaching to which these beds have been subjected varies greatly, and approximately keeps pace with the process of oxidation. In the cuts along the Chicago Great Western railway on sections

8 and 17, in Timber Creek township, these facts are beautifully illustrated. The maximum thickness of Kansan till exposed here is about fifteen feet, covered with 3 to 10 feet of loess, the latter being the thickest upon the hill flanks. Near the line of contact the till is a deep red-brown in color and thoroughly leached. Passing downward, the color becomes lighter and the leaching less perfect. The lower five feet of the partially oxidized zone is of a faded yellow color, and lime concretions similar to those found in the loess which mark the incipitent stages of leaching are very abundant.

The pebbles and bowlders consist chiefly of granites, greenstones and gneisses. In the eastern half of the county fragments of limpid quartz and cherty limestones are very common, while quartzites occur infrequently. Many of the bowlders are fractured and striated. The granites and gneisses often crumble on exposure. Fragments of coniferous wood are not uncommon inclusions in the lower portion of the formation.

The Kansan till covers the whole county save where it has been removed by erosive agencies. The thickness of the sheet varies from a few feet, where it caps the outliers of the Kinderhook to more than one hundred feet in the uplands of the south and west, with an average thickness of little less than the latter figure. The oxidized portion is usually rather more than ten feet thick.

BUCHANAN.

The retreat of the Kansan ice was closely followed by a season of vigorous erosion and a working over of the newly deposited drift. This was a time of gravel accumulation. Well rounded bowlders of Kansan till are found in these gravel beds and may be taken as evidence of the still frigid climate, for it is reasonable to presume that fragments of clay would not permit attrition and transportation unless frozen. At Albion these gravels attain a thickness of about two feet and are typically developed. They are very much

coarser at this point than those referred to the Aftonian. The gravels near Gifford are probably of the same age, but are finer textured and distinctly stratified. During the remainder, and by far the greater portion of the inter-glacial interval, the surface was profoundly eroded, oxidized and leached.

IOWAN.

The Iowan ice traversed the northeast part of Marshall county and left evidence of its visit in the form of a thin sheet of till, and a goodly sprinkling of bowlders, some of

FIG. 31. Iowan bowlder, red granite, situated two and a half miles north of Marshalltown.

which are of enormous size. Unlike the Kansan, the Iowan contributed but little bowlder clay. Exposures of Iowan till may be observed at the Albion mills, Rockton, the cuts along the wagon roads in the northwest corner of section 2, Tp. 89 N., R. XVIII W., and various places between sections 5 and 6, Tp. 84 N., R. XVII W. This drift sheet never attains more than a few feet in thickness, and over perhaps the greater portion of the area, the bowlders, many of which occur well up the hill flanks, are the only witnesses of its presence. The Iowan till is light to bright yellow in color and is imperfectly oxidized and leached. It is sandier and lacks the tough, plastic char-

acter of the Kansan. The bowlders, both great and small, are prevailingly granites, and are much fresher than those common to the older drifts.

Thé Iowan ice was undoubtedly thin in this region, and the extreme advance of the attenuated edge is probably approximately outlined by the Iowa river, but no bowlders were observed on the flood plain below Albion.

LOESS.

The loess is a homogeneous, siliceous silt varying from light buff to a brownish buff in color. It in some measure resembles the drift after the coarser and finer materials have been removed. The constituent particles vary in size from

FIG. 38. Stratified loess, in clay pit of Sieg and Size, west of Marshalltown on the Iowa Central railway.

the finest silt to fine sands and usually present sharp angles. Lime concretions, *losspuppen* and *lossmanchen*, are often present in great numbers. Structurally, the deposit is uniformily massive, although in many exposures stratification lines are plainly visible. Typical loess possesses the peculiar physical property by virtue of which it tends to maintain a vertical scarp, regardless of its apparently incoherent character, and it

south, extending from the northeast corner of Bangor township to the southwest corner of Green Castle township. There are reëntrant angles where the principal streams make their exit from the measures, with the exception of Middle Timber creek; there being an extension at this point. A prolongation of the coal measures extends westward into Iowa and Liscomb townships and may have been at one time continuous with the outlier in Vienna and Taylor townships, which marks the extreme eastward limit of the Des Moines in the county. Outcroppings of the coal measures are few and unimportant, so perfect is their concealment by the glacial debris. At certain points along the Iowa river northwest of Albion on Honey creek, a thin coal seam along with carbonaceous shale may be noted. In Timber Creek township a heavily bedded, red sandstone appears along a tributary of Linn creek, near the Chicago Great Western railway on sections 8 and 9. Outcrops of the same beds may be observed near the water level on the Middle Timber in sections 26 and 34. Away from the margin there are no exposures of the Des Moines in the region. The deeper wells in the vicinity of State Center undoubtedly penetrate the coal measures, which consist largely of shales. In sinking a well for Emanuel Hepner, Tp. 85, N., R. XVII W., Sec. 30, Se. qr., Ne. ¼, the following sequence of strata was reported.

	FEET.	INCHES.
Loess and drift	120	
Sandy, shelly rock, greenish yellow	2	
Coal		6-8
Red sandstone, soft	16	
Argillaceous limestone, very hard	1	
Argillaceous shale, light, ash-color	13	
Coal, carbonaceous shale and fire clay	6	
Hard, gray limestone (penetrated)	10	

Other wells in the vicinity are reported to exhibit a similar sequence. The Hepner well seems to be near the center of the outlier and hence the maximum thickness of the measures in this region may be taken as approximately forty feet. The Des Moines is doubtless much thicker in the western portion

of the county, but at present no well authenticated records are at hand.

Here, as elsewhere in Iowa, the Des Moines stage of the Upper Carboniferous consists essentially of shales and sandstones, with occasional layers of argillaceous limestones and seams of coal, all of which are interbedded in an intricate manner. The shales predominate in Marshall county and vary structurally from massive structureless clays through clayey shales to fissile shales; texturally form the purest shales through arenaceous shales to argillaceous sandstones. Colors are equally variable from the gray-white fire clays to the jet-black carbonaceous shales.

The prevailing sandstones are in shades of red, but in other regions, where better exposed, they are found to be equally as variable in physical properties as are the shales.

So far as at present known the argillaceous limestones and coal seams are sparingly developed in this territory.

PLEISTOCENE.

With a few unimportant exceptions where the larger streams have succeeded in cutting through and exposing the older formations, the Pleistocene deposits form a continuous mantle over the entire county. They are composed essentially of bowlder clays, sands, gravels and silts, often interbedded and intermingled in a most complex manner. Bowlders are not uncommon attendants to this most heterogeneous assemblage. The average thickness of the glacial debris on the uplands in this region, is upwards of 100 feet, and the present surface features are sculptured almost wholly in this material. At certain points in the county much greater depths are attained. In Eden Tp. on the northwest quarter of section 8, 190 feet was reported; Jefferson Tp., Sw. qr. of Sec. 22, 220 feet; Marietta Tp., Sw. qr. of Sec. 25, 212 feet; Liscomb Tp., Nw. qr., Sec. 22, 260 feet; Taylor Tp., Se. qr., of Sec. 1, 300 feet, and on the Sw. qr., 400 feet of drift was penetrated. In the latter township there seems to be a rock-

bound gorge trending northeast-southwest, bisecting sections 1 and 11, and more than a half mile in width. The southern wall of the gorge is apparently very abrupt, while the north wall rises gradually. The rock rises to seventy or eighty feet of the surface within half a mile southeast of the line of the gorge. Northward the rock is reached 190 and 180 feet below the surface on the Sw. and Nw. qrs. of section 2, respectively. The inequality of the slopes of this buried channel is analogous to that of the great majority of the Iowa streams of the present day. The south flank is almost universally the more abrupt.*

Although there are occasional hints of preglacial channels and depressions, none can be mapped definitely, and the general testimony of the drift wells is that the preglacial topography was milder than that of the present time. The type of topographic maturity. the pure plain, is suggested.

Marshall county has been subjected to at least three and perhaps four distinct ice invasions, separated by intervals of vigorous erosion and surface corrugation, or surface silting. The first two ice sheets were followed by gravel trains, while the last two were succeeded by intervals of surface silting and alluvium forming, respectively. The sequence of events may be described briefly in chronological order, and the corresponding deposits arranged stratigraphically as follows.

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DRIFT SECTION AT ALBION.

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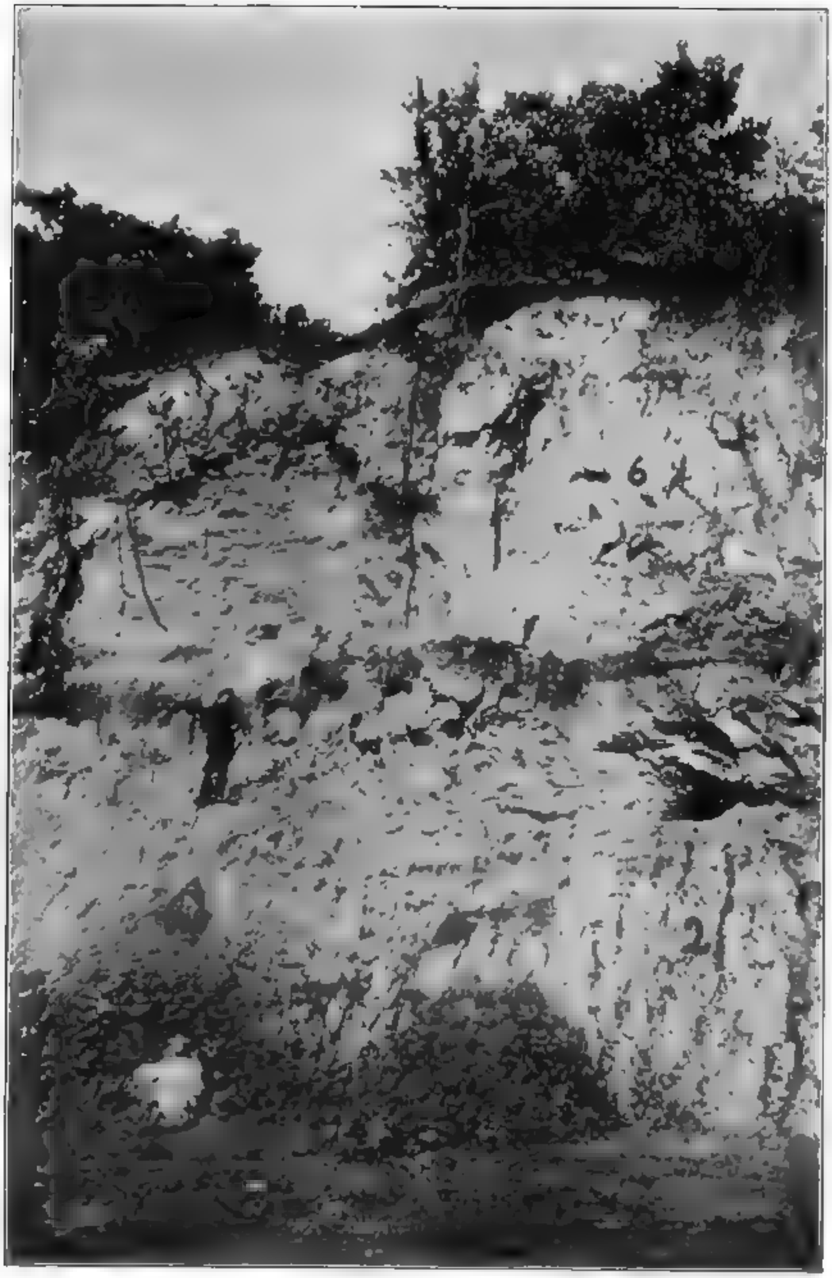

DRIFT SECTION AT ALBION.

SUB-AFTONIAN.

No till sheet below the Kansan has certainly been identified in this region. At the Albion mill, about ten miles northwest of Marshalltown, the following sequence of deposits may be observed, the basal members of which are pre-Kansan, and may be the equivalent of the sub-Aftonian.

ALBION SECTION.

		FEET.
6.	Loess, stratified sand and silt below	20
5.	Yellow till, apparantly wanting in places and often represented by characteristic bowlders only. (Iowan)	0–1½
4.	Gravel, bowlders four or five inches in diameter present, granitic members often much decayed; limestone pebbles common; bowlders of Kansan adorned with pebbles noted. (Buchanan)	2
3.	Till, upper portion oxidized a deep reddish brown, the lower portion unoxidized and gray-blue in color; jointed structures prominent throughout. (Kansan)	5
2.	Sand and gravel, stratified, coarser below; oxidized in streaks and bands approximately parallel to bedding planes. (Aftonian)	10
1.	Blue till* (Sub-Aftonian)	10

At the well put down in section 7, in Warren township, for Wm. M. Wallace, the drillers' record is as follows:

	FEET.
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The above records at least suggest the presence of the pre-Kansan till sheet, but additional data are necessary before more explicit statements can be made concerning its characteristics and distribution.

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At the base of the Albion section ten feet of stratified sand and gravels may be observed. These beds were laid down,

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in large part, through the agency of running water. Many of the pebbles and small bowlders bear polished, striated or facetted surfaces, yet the granitic members are oftentimes in an advanced stage of decay. The relation of this deposit to the Kansan is unquestionable, because till of the Kansan age rests immediately upon these beds. Gravels similarly related to the Kansan have been reported from various parts of the county, and the maximum thickness attained is about thirty feet.

The presence of a well marked terrane consisting of sands and of gravels, many of the pebbles and small bowlders of which bear the unmistakable imprints of glaciation, almost necessitate a preëxistant glacier and its universal product, the till sheet. *A priori*, this fact in itself would be sufficient reason for suspecting the presence of pre-Kansan glaciation (sub-Aftonian drift sheet).

KANSAN.

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BUCHANAN.

The retreat of the Kansan ice was closely followed by a season of vigorous erosion and a working over of the newly deposited drift. This was a time of gravel accumulation. Well rounded bowlders of Kansan till are found in these gravel beds and may be taken as evidence of the still frigid climate, for it is reasonable to presume that fragments of clay would not permit attrition and transportation unless frozen. At Albion these gravels attain a thickness of about two feet and are typically developed. They are very much

coarser at this point than those referred to the Aftonian. The gravels near Gifford are probably of the same age, but are finer textured and distinctly stratified. During the remainder, and by far the greater portion of the inter-glacial interval, the surface was profoundly eroded, oxidized and leached.

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FIG. [illegible]. Iowan bowlder, red granite, situated two and a half miles north of Marshalltown.

which are of enormous size. Unlike the Kansan, the Iowan contributed but little bowlder clay. Exposures of Iowan till may be observed at the Albion mills, Rockton, the cuts along the wagon roads in the northwest corner of section 2, Tp. 85 N., R. XVIII W., and various places between sections 5 and 6, Tp. 84 N., R. XVII W. This drift sheet never attains more than a few feet in thickness, and over perhaps the greater portion of the area, the bowlders, many of which occur well up the hill flanks, are the only witnesses of its presence. The Iowan till is light to bright yellow in color and is imperfectly oxidized and leached. It is sandier and lacks the tough, plastic char-

acter of the Kansan. The bowlders, both great and small, are prevailingly granites, and are much fresher than those common to the older drifts.

The Iowan ice was undoubtedly thin in this region, and the extreme advance of the attenuated edge is probably approximately outlined by the Iowa river, but no bowlders were observed on the flood plain below Albion.

LOESS.

The loess is a homogeneous, siliceous silt varying from light buff to a brownish buff in color. It in some measure resembles the drift after the coarser and finer materials have been removed. The constituent particles vary in size from

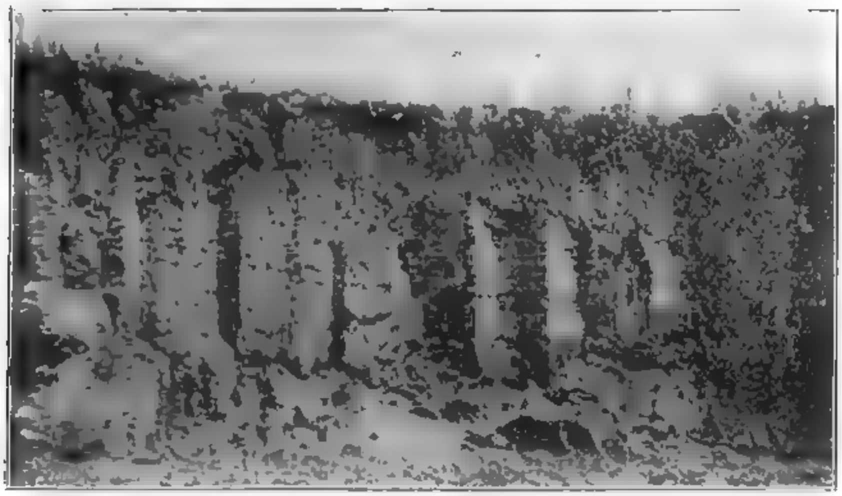


FIG. 22. Stratified loess, in clay pit of Sieg and Size, west of Marshalltown on the Iowa Central railway.

the finest silt to fine sands and usually present sharp angles. Lime concretions, *losspuppen* and *lossmanchen*, are often present in great numbers. Structurally, the deposit is uniformily massive, although in many exposures stratification lines are plainly visible. Typical loess possesses the peculiar physical property by virtue of which it tends to maintain a vertical scarp, regardless of its apparently incoherent character, and it

thereby greatly sharpens the contour lines of the regions thus clothed.

With the exception of the territory covered by the Wisconsin till and a small area near the northeast corner, the loess mantles the entire county, irrespective of altitude, save where removed by the streams. It is thickest in the vicinity of the probable margin of the Iowan ice, that is along the Iowa river, where it attains a maximum vertical measurement of upwards of twenty feet. In this region the deposit always grades downward imperceptibly into stratified sands. The loess is relatively both thicker and sandier near the greater waterways than upon the uplands. On many of the hills near the Iowa and, in a less degree, its greater tributaries, the upper silt has been removed and the sub-loessial sands comprise the present surface. This is notably true of the hills south of Albion and in Marshalltown and vicinity. The Chicago Great Western, crossing the divide between Linn and Timber creeks, lays bare some interesting facts concerning the distribution of the loess. While all of the hills are wholly loess mantled, the deposit gradually thickens from the summit to the slopes and is largely dissected out in the valleys.

The quarries near Le Grand expose from 15 to 20 feet of loess which is slightly sandy above, loess and sand interstratified in the middle, and almost pure sand at the base of the section. Loess concretions and fossils were not noted. At the clay pits west of Marshalltown, the loess is beautifully stratified throughout and becomes more siliceous below. Lime concretions occur sparingly, but no fossils were found. The above section may be considered typical for the immediate vicinity of the Iowa river. Two miles west of Marshalltown a road cut exhibits the following section.

	FEET.
Typical loess, slightly arenaceous below	6 to 8
Interstratified sand and loess, exposed	4

Fossils are abundant in the upper portion and persist in diminished numbers where lines of stratification are apparent. The principal species identified* are listed below.

* Professor Shimek kindly identified the fossils found in the loess.

Succinea avara Say, very abundant.
Succinea obliqua (Say).
Zonites shimekii Pilsbry.
Patula striatella Anthony.
Vallonia pulchella Mueller.
Zonites fulvus Draper.
Pupa muscorum Linnaeus.
Pupa alticola Ingersol.
Pupa pentadon Say.

One-half mile south of Bangor, fifteen feet of loess are exposed. The lower portion is filled with root casts, the largest of which measure an inch and a half in diameter. The matrix consists of interstratified, light colored sand and silt, the result of the removal of the iron constituents and the concretionary casts. Numerous concretions and fossils occur in the upper portion, the most common fossils observed being:

Succinea avara Say, very abundant.
Pupa pentadon Say.
Pupa muscorum Linnaeus.
Helicodiscus liaeatus Say.

About one and one-half miles north of State Center the above section is almost perfectly duplicated in all particulars. Fossils were noted in the clay pits at Rhodes and Melbourne and other points, but whenever observed, *Succinea avara* Say constituted more than one-half the specimens.

Origin of the loess.—Even since the publication of von Richthofen's "China," with the description of the Chinese loess, and the formation of the "Æolian Hypothesis" by that distinguished geologist and writer, the origin of this most anomalous deposit has been a fruitful subject for hypotheses both in this country and in Europe. It is not intended in the present discussion to espouse any particular theory, but rather to record the more salient features of the Marshall county loess and suggest their probable significance.

The stratified sub-loessial sands and interstratified sand and silt render plausible a subaqueous origin. But whether these conditions were brought about by a general depression of the surface and consequent ponding of the streams, or by drainage obstructed through the existence of an ice dam, the facts at hand do not warrant a conclusion. The general distribution of the loess, the absence of structural characters peculiar to waterlaid materials, the presence of land mollusks, some of which are now native even to arid regions, certainly lend credence to an æolian hypothesis. The angularity of the constituent particles has also been considered favorable to wind as the transporting agent. The validity of this inference is not well founded. It is an established fact that while the coarser sand grains are usually rounded through mutual attrition and impingement against obstructions, the cushioning action of the water adequately protects the finer sands and silts so that they maintain their angularity though transported great distances.

WISCONSIN.

The Wisconsin ice was represented in Iowa by a great tongue-shaped lobe, whose apex reached Des Moines, and which by a flank movement invaded the western border of Marshall county. The accompanying till sheet is second only to that of the Kansan. The upper portion of the Wisconsin till is slightly oxidized to a faint, dull yellow color and is succeeded downward by a blue bowlder clay less massive than that of the Kansan. Samples of both the oxidized and unoxidized portion effervesce freely when treated with cold, dilute hydrochloric acid. Lime balls are very abundant in many places. Bowlders are much more numerous in this region than in any of the older drift sheets, but are of smaller size than those of the Iowan age. The predominating types are gray and red granites, with less abundant quartzites and gneisses. Basic rocks are comparatively rare. The bowlders present a strikingly different aspect from those peculiar to

the subjacent Kansan, being as fresh as when they were broken from the parent ledge.

ALTAMONT MORAINE.

The limits of the Wisconsin lobe are marked in many places by a hummocky aspect of the surface with "kettle holes" and ponds liberally interspersed. This is the place where the melting glacier dumped its load of rock debris, which had been gathered during its journey from the far north and is technically known as the terminal moraine. In Marshall county

FIG. 33. Typical Wisconsin drift topography showing shallow "kettle-holes." Between State Center and St. Anthony.

the terminal moraine is but feebly developed. West of State Center is the nearest approach to a moraine in the region. Although distinctively morainic characters are but mildly expressed, the decided change in general surface configuration in passing from the older to the newer drift, facilitates the easy establishment of the boundary of the Wisconsin lobe.

GLACIAL SCORINGS.

The salient portions of the Kinderhook at Le Grand and Timber Creek, and the coal measure sandstone on section 8, Tp. 83 N., R. XVIII W., have been deeply planed and striated by the great ice sheets which traversed these regions. The

surface in all cases faces north, and all of the points are situated on the south bank of the Iowa river and the tributaries mentioned. No examples of rock scoring could be found on the opposite side of the flood plain. This may be considered additional evidence as to the preglacial character of the principal waterways. The northern slopes are protected by an accumulation of talus, while the southern flanks have been scraped clean of the rock debris and profoundly planed owing to a change in the gradient. The scorings and finer striæ were hermetically sealed by a layer of impervious blue clay and their state of preservation approaches perfection. At Le Grand the striæ trend south, 24° east; at Timber Creek they trend south, 25° east; at Sec. 8, Tp. 83 N., R. XVIII W., south, 20° east.

ALLUVIUM.

The alluvium is an important deposit in Marshall county. All of the principal streams on the older drift sheets flow through alluvial bottoms, while the Iowa river traverses a belt of this deposit which averages more than a mile in width. Most of the deposits which are mapped as alluvium are not wholly riverlaid material, but rather a mixture of loess and fluviatile deposits. Many of the streams have been alluvium making since the retreat of the Kansan ice. Northeast of Marshalltown on the broad bottomland of the Iowa, the finer debris has been removed in large part and extensive sand flats result.

Geological Structure.

The Kinderhook beds constitute a conformable series but are overlain unconformably by the Des Moines series. After the deposition of the Lower Carboniferous rocks, the general upward movement of the continent brought the whole of Marshall county above the level of the great Mediterranean sea to the southwest. Then followed an extended interval of denudation. The youthful surface was set upon by the erosive agents and dissected by streams until the physiography of the region was as strongly characterized as is the

1897.

LEGEND

GEOLOGICAL FORMATIONS.

ALLUVIUM.

WISCONSIN DRIFT.

present configuration. This was followed by a season of depression until the valleys were submerged, and finally perhaps, the whole surface of the county was near or below sea level and received contributions of sands, silts and clays, with some vegetable debris, which were lain down unconformably upon the older rocks. The deposits were compacted into sandstones, shales and coal seams, and constitute the coal measure series. The irregularity of the outline of the present Carboniferous deposits is due to the irregularities of the preëxisting surface. This period of deposition was closed by reëlevation the surface which was profoundly eroded through an immense interval of time; through, perhaps, the whole Mesozoic and the greater portion of the Cenozoic eras. The Pleistocene deposits lie unconformably upon all of the Paleozoic rocks and each drift sheet rests unconformably upon its predecessor. Although the surface may have oscillated up and down many times, the movement was continental and the strata are consequently approximately parallel.

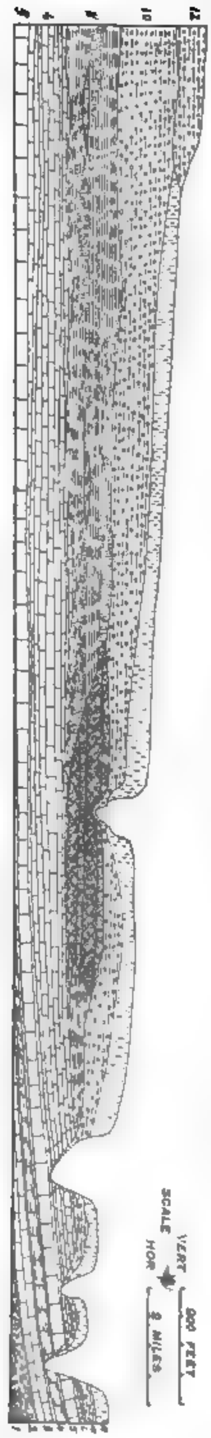


FIG. 34. Le Grand-State Center section. 1, Hannibal shales (?); 2, blue sandstone; 3, oölite; 4, chert beds; 5, magnesian limestone; 6, gray and brown limestone; 7, Marshalltown shales; 8, coal measure shale and sandstone; 9, coal measure sandstone; 10, Kansan till; 11, loess; 12, Wisconsin till. Numbers 2-6 make up the Le Grand beds.

ECONOMIC PRODUCTS.

Building Stone.

As has been said, the stratified rocks belong wholly to the Paleozoic era; and the Mississippian and Pennsylvanian series underlie about equal areas in the

county. The former consists essentially of limestones. The principal outcrops where quarry operations have been carried on are in the vicinity of Quarry and Le Grand, along the Kinderkook escarpment, and and on Timber creek. The Pennsylvanian series consists chiefly of shales, and a dull red sandstone is the only stone worthy of mention in this connection.

KINDERHOOK.

The most valuable quarry products in the county are derived from the basal member of the Mississippian series. In the southeastern portion of the state there are extensive outcrops of rocks of Kinderhook age, which consist chiefly of shales. In central Iowa, and in Marshall county in particular, the Kinderhook beds take on a calcareous facies and afford some of the best building stone to be found in the state. These beds are the more valuable because of their availability. The principal outcrops are located near the main lines of the Chicago & Northwestern and Iowa Central railways. The overlying glacial deposits are comparatively thin and may be removed at a minimum expense. The principal layers sought are the oölite and magnesian limestone, but the entire series is utilized.

LE GRAND QUARRY COMPANY.

The pioneer in the quarry industry, as well as the largest company operating in the county at the present time, is the Le Grand Quarry Co. with their central office in Marshalltown. The company owns and operates quarries at Quarry, Rockton and Timber Creek.

Quarry.—Three quarries are connected with the C. & N.-W. Ry. by branch lines at this point. Active operations were begun as early as 1860, when a limited quantity of building stone and lime was produced. Two years later the railway tracks were extended into the quarries, and the company has maintained a steady growth since. The manufacture of lime was discontinued some years ago.

The quarry plant is provided throughout with the most approved machinery. The equipment consists of steam crusher, gang mills, steam drills, derricks, lathes and planers; and quarrying and stone working is carried on most expeditiously and according to modern methods. The Le Grand beds in their entirety have been exploited to some extent, though the position of the blue sandstone renders it almost unavailable at present. (See Le Grand section.) The oölite and upper magnesian limestone layers afford the most valuable products, although the chert beds and rubbly limestone, along with the debris consequent to quarry operations, are worked up into riprap, concrete, ballast, etc., and constitute an important source of revenue to the company.

The chief building stones put upon the market are known commercially as oölite limestone, Iowa marble, Iowa caen stone and blue limestone.

The basal blue sandstone has not been sufficiently explored and tested to such an extent as to allow its merits as a building stone to be stated definitely. Small quantities of the stone have been removed from the east quarries, and certain blocks are now being tested as pavers in the streets of Marshalltown with some promise of satisfactory results.

There are two grades of oölitic limestones. The lower layer measures three and one-half feet in thickness and is coarse grained. The upper twelve feet is finer textured and consists of layers of the following thicknesses, respectively, from below upwards: 24, 26, 36, 6, 9, 8, 12 and 14 inches. The oölite is quarried only at the two east quarries, the dip of the beds and the slope of the river carrying the layers below the bed of the stream before the west quarry is reached. Formerly, the coarse, heavy basal layer was used for constructional purposes, but of recent years experience has demonstrated that it suffers disintegration when exposed for a season to atmospheric conditions. The fine-grained layers are close, even-textured and stand the test of time well. This is not only shown in artificial structures where the

blocks have maintained their angularity against sunshine and storm for upwards of a quarter of a century, but better still in the natural exposures where these layers stand out in bold relief. The oölite is composed of small, rounded, concretionary calcareous grains imbedded in a semi-crystalline matrix of cementing material of the same composition. Many of the concretions contain small angular siliceous grains. The unaltered rock is of a gray-blue color, while the weathered portion assumes a yellowish hue. Certain of the layers are highly fossiliferous and as the rock takes a high polish the beautiful effects are much enhanced, and this variety is known commercially as fossilite marble. Such slabs need to be collected with some care, for small grains of iron pyrites are often present and produce black stains when subject to moisture.

The upper portion of the magnesian limestone furnishes both the Iowa "marble" and the Iowa "caen stone," the former containing a higher percentage of $MgCO_3$. The Iowa marble occurs in heavy beds from two to three and a half feet in thickness. The slightly weathered portions are plain, light buff in color, while the weathered layers are of a a deeper color and beautifully veined with iron oxide. The stone receives a high polish, but like other limestones does not retain it when exposed to atmospheric agencies. It is very desirable for panelling and all parts of inlaid work when kept dry, aside from its qualifications as a first class building stone.

The caen stone is similar in color to the marble, but is softer, more tenacious and of lower specific gravity. It is especially adapted for carvings and molding.

A ledge of blue limestone lies between the chert beds and the oölite and also immediately above the chert beds. This limestone is very hard, compact and somewhat irregularly bedded, which renders quarrying and working rather difficult. The stone is used to some extent as a coursing stone and is very durable, but its untractable character renders its production expensive and it is mainly used as ballast.

The brown subcrystalline limestone with its interstratified oölitic layers affords some coursing stone and would be considered desirable for foundations in regions where building stone is scarce, but by far the greater quantity is transported to the crusher.

Rockton.—Active quarry operations have not been carried on at this point for several years. The beds worked comprise the brown subcrystalline limestone with the interbedded oölitic layers and the upper layers of the magnesian limestone. The characteristics of the beds exposed here are similar to their equivalents at Quarry. The upper oolite is perhaps heavier bedded and more important than at the last mentioned place.

FIG. 85. The Le Grand beds as exposed on Timber creek at the Iowa Central railway crossing. The section is, in part, along the line of a natural fissure and illustrates the differential weathering of the beds. 1, Blue limestone; 2, upper oölite; 3, brown and gray subcrystalline limestone.

Timber Creek.—The Le Grand Quarry Co. has been developing rapidly their quarry interests at this point during the past few years. A side track is laid in from the Iowa Central railway and the plant is well equipped with modern machinery. The beds operated are the same as those at Quarry from

the magnesian limestone upwards. As has been mentioned, the magnesian limestone differs in color from its homologue at Quarry and Rockton. At the latter places shades of buff prevail, while at the Timber Creek quarries the chief beds are a gray-blue with occasional layers in part light yellow. The fact is emphasized that the predominating color in the unaltered Le Grand beds is a gray-blue, which is changed to tones of buff and yellow through weathering agencies. Here, as in

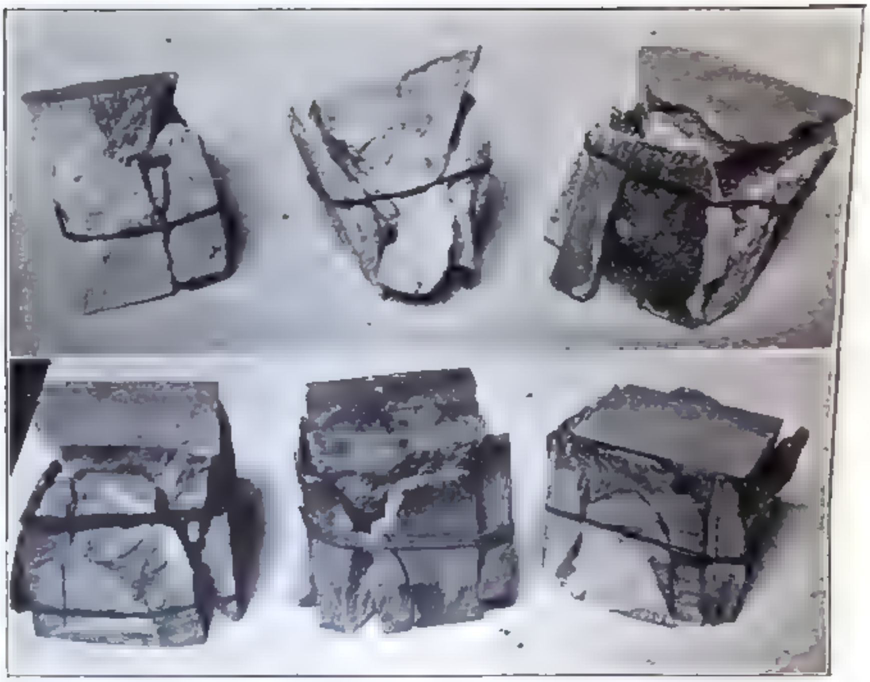


FIG. 36. Characteristic fractures of Le Grand building stone. Upper row, oölite; lower row, magnesian limestone.

other places, the magnesian layers succumb less readily to disintegrating forces than the associated beds.

The upper oölite and brown subcrystalline limestone are of more importance here than at the exposures along the Iowa river.

The Le Grand Quarry Co. employ on an average 200 men during the working season, and the daily output is about a train load.

TESTS OF THE LE GRAND STONE.*

The principal varieties of the Le Grand stone were subjected to three series of tests, viz:

1. Strength and ratio of absorption to determine the compactness of the stone, and hence its ability to withstand the atmospheric agencies.

2. Freezing and thawing alternately, and carefully noting the loss in weight and strength; and hence determining the tendency of the stone to disintegrate or weaken under the action of frost.

3. Chemical analysis to determine the relative amounts of desirable and deleterious constituents present.

In previous investigations on building stones, rectangular blocks of various sizes and shapes have been employed. The consensus of opinion of the highest authorities on the subject at the present time favor the two-inch cube as possessing the most convenient dimensions and giving the most satisfactory results. In the present investigation the two-inch cube was adopted. Great care was exercised in their preparation in order to guard against the production of incipient fractures through the impact of tools, and thereby lessening the strength. The blocks were sawed out approximately with the diamond saw, and then reduced to the proper dimensions by grinding. The results are tabulated in the subjoined tables.

* The mechanical tests were made in large part by Messrs. G. W. Zorn and J. W. Elliott under the personal supervision of Prof. A. Marston, in the Dept. of Civil Engineering of the Iowa Agricultural College. The chemical analyses were made for the survey by Prof. G. E. Patrick.

TABLE I.

MECHANICAL* TESTS.

	KIND OF STONE.	Height of cube.	Surface dimensions.	Area.	BREAKING LOAD IN LBS. Spalling began.	BREAKING LOAD IN LBS. Failure.	LOAD PER SQUARE INCH. Spalling began.	LOAD PER SQUARE INCH. Failure.	REMARKS.
	†Oölite, fine grained, northeast quarry	2 03	1.98x1.99	3.94	....	46,680	......	11,600	Failure accomp'n'd by much shattering.
4	do heavy bedded	2 02	2.00x2.00	4.00	47,500	53,800	11,875	13,450	do
5	do " "	1.97	2.00x1.98	3.96	54,000	59,300	13,636	14,900	do
6	do thinly bedded	1.96	1.96x1 96	3 84	39,400	39,400	10,260	10,260	do
22	Oölite, light, southeast quarry	2.05	2 00x2 04	4.08	42,000	52,000	10,280	12,740	do
23	do	1.97	2.00x2.00	4.00	57,000	57,000	14,250	14,250	do
43	do heavy bedded	2 00	2 00x2.00	4.00	38,000	53,000	9,500	13,250	do
	†Iowa marble, plain, west quarry	1.98	1.98x1.97	3.90	....	47,120	....	12,080	All samples of the Iowa marble broke in such a way as to show much elasticity.
16	do	2.00	2.02x2.04	4 12	60,500	63,300	14,685	15,120	
	†Iowa marble, colored	2.00	2 02x2.01	4.06	....	37,060	....	9,128	
27	Blue limestone, northeast quarry	2 00	2.02x2.02	4.08	....	....	....	....	63,000 lbs. applied, no effect.
24	do	1.99	2 00x2.02	4.04	....	....	....	....	63,000 lbs. applied, no effect.
11	Fossiliferous limestone, northeast qr.	2.00	2 00x2.00	4.00	42,000	....	10,500	....	Sustained 65,800 lbs. without further rupture.
12	do	2.00	2.00x2.00	4 00	63,300	....	1,582	....	Beyond capacity of machine to crush.
15	do southeast quarry	1.99	2.00x2 00	4.00	43,700	....	10,925	....	Sustained 65,800 lbs. without further rupture.
26	do	2 00	2.00x2.02	4.04	58,300	66,400	14,430	16,435	
28	do west quarry	1.97	2.00x1.98	3.96	38,700	38,700	9,773	9,773	
33	Blue limestone, Timber Creek	1.98	1.98x2.00	3.96	28,000	34,500	7,070	8,712	
34	do	2.00	1.98x2.00	3.96	29,000	33,200	7,320	8,383	

* An Olsen testing machine was used in making these tests. The specimens were placed between two steel plates, the upper being fixed, while the lower was free to oscillate in a hemispherical protuberance, which fitted accurately in a well lubricated socket, thus distributing the pressure equally when the parallelism of the cube faces was imperfect. The load was applied at a uniform rate.

† Tests made under the direction of Prof G W Bissell, Dept. of Mechanical Engineering, I. A. C.

TABLE II.

FREEZING TESTS.*

Number.	KIND OF STONE.	Height of cube.	Surface dimensions.	Area.	BREAKING LOAD IN LBS.		LOAD PER SQUARE INCH.		Loss in weight in per cent.	REMARKS.
					Spalling began.	Failure.	Spalling began.	Failure.		
20	Oölite, fine grained, northeast quarry	2.05	2.00x2 08	4 16	55,700	56,400	13,390	13,558	0.0014	Loud report.
21	do	2.08	2.00x2.08	4 16	26,000	-------	6,250	14,280	0.0013	Sustained 59,400 lbs. Very slight spall at 26,000 lbs.
38	Oölite, fine grained, southeast quarry	1.99	1 97x2.00	3 94	50,000	60,000	12,690	15,230	-------	Loud report and cube much shattered.
44	do	2.00	2 00x1.96	3.92	34,000	55,700	8,673	14,210	-------	do
46	do	2 02	1 97x1.97	3.88	50,000	56,500	12,890	14,560	-------	do
19	Iowa marble, west quarry	1.96	2 02x2.02	4 08	50,000	56,500	12,255	13,850	0 0007	Broke with a loud report.
17	do	1.92	2.00x2.00	4 00	42,600	52,700	10,650	13,175	0.0008	do
18	do	2.00	2 04x2 02	4.12	38,000	51,700	9,225	12,550	0 0009	do
14	Blue limestone, northeast quarry	2 00	1.98x1 97	3 90	------	------	-------	15,360†	-------	59,400 lbs. applied without effect.
3	Fossiliferous limestone, northeast qr.	2.00	2 00x2.02	4.08	------	------	-------	14,560†	-------	59,400 lbs. applied without effect.
2	do	1.98	1.97x2.00	3.94	55,600	------	14,035	14,900†	-------	59,400 lbs. sustained.
29	Fossiliferous limestone, west quarry	1 98	2.04x2 02	4 12	35,900	40,000	8,715	9,710	-------	Weak report.
30	do	1.97	1.99x1.96	3.91	30,500	35,000	7,800	8,950	-------	do
32	Blue limestone, Timber Creek	2 00	2 04x2.01	4 10	28,000	36,300	6,830	8,850	------	Slight report.‡
45	do	1.96	1.98x1 96	3 88	32,700	32,700	-------	8,430	-------	

* The cubes were placed in distilled water until completely saturated, after which the specimens were encased in cotton batting saturated with distilled water and placed in wooden trays, eight by eight inches and two inches deep, provided with wire bottoms. The trays after being securely packed were placed in the refrigerator and kept at a temperature of from 17° to 19° F. for forty-eight hours. Then they were removed from the refrigerator and subjected to a temperature of 70° F. for twenty four hours. This process was repeated six times. The specimens were afterwards subjected to refrigeration and thawing ten times, but the conditions were less constant than in the first six. In the latter series the minimum temperatures ranged from 21° to 32° F.

† The above table shows that the blocks suffered no appreciable loss in weight or strength during the investigation. It is highly probable that lower temperatures would have given very different results.

‡ In spite of the apparent weakness, low specific gravity and rather high percentage of absorption, the quarry face along natural fissures shows this stone to be one of the most durable quarried in the county. (See figure 30.)

TABLE III.

ABSORPTION AND SPECIFIC GRAVITY TESTS.

Number.	NAME OF STONE	LOSS OF QUARRY WATER THROUGH DRYING—WT. IN GS.			WATER ABSORBED AFTER IMMERSION, EXPRESSED IN PERCENTAGES, OVER DRY WEIGHTS.				Specific gravity.	Weight per cubic foot in lbs.	REMARKS.
		0 hours.	1 hour.	5 hours.	1 hour.	3 hours.	24 hours.	144 hours.			
20	Oōlite, fine grained, northeast quarry	350.90	350.70	350.58	0.85	1.59	2.66	2 75	Average, 2.57 lbs.	160.5 lbs.	
21	do	348 91	348.79	348 63	1.56	3 26	3.95	4.05			
38	Oōlite, south quarry	335 03	334.99	334.97	1.20	1.50	2 50	2.61			
44	do	333 90	333.79	333.63	0.71	1 85	2.11	2.20			
46	do	326.90	326.30	325.63	1 50	1.96	2.55	2.64			
19	Iowa marble, west quarry	323.10	327.70	322.47	2 33	3.02	3.60	3.87	2.54	153.2	Average.
17	do	309.40	309 00	308.01	1.81	2.43	3.31	3.57	......	......	
18	do	320 90	319.20	318.20	2.31	3.06	3.97	4.37	......	......	
10	Blue limestone, northeast quarry	348.70	348.21	348.19	0.48	0.86	1.86	2.02	2.77	173.0	
3	Fossiliferous limestone, northeast quarry	344.00	343.78	343.52	0.72	1.01	1.72	1.79	2.60	162.5	
2	do	353.86	353 40	353.20	0.22	0 50	0.70	0.77	......	......	
30	Fossiliferous limestone, west quarry	311.00	310.90	310.87	0.06	0.84	1.65	1.79	......	......	
29	do	340.91	340.46	340.38	0 22	0.84	1.64	1.79	......	......	
32	Blue limestone, Timber Creek	320.76	320.36	320.00	2 03	3.01	3 17	3.36	2.30	144.0	
45	do	285 74	285.36	285.15	4.00	4.67	5.41	5.65	......	......	

TABLE IV.

CHEMICAL ANALYSES OF LE GRAND STONE.

CONSTITUENTS.	Fine grained oölite.	Blue limestone.	Iowa caen stone.	Iowa marble, plain.	Iowa marble, colored.	Stratified limestone.
Hygroscopic water (loss at 100° C.)	0.03	0 09	0.06	0.04	0 06	0.04
Combined water (expelled by ignition)	0.13	0.21	0.15	0.19	0.12	0.12
Silica and insoluble	0.77	0.96	1.24	0.80	0.89	1.22
Carbonic acid, CO_2	43.62	43.30	43.79	44.85	44.76	43.85
Alumina, Al_2O_3	0.05	0.07	0.18	0.14	0.15	0.14
Iron, Fe_2O_3	None	None	0.15	0.15	0.31	0.26
Iron, FeO	0.09	0.27	0.09	0.19	0.10	0.09
Lime, Ca O	55.05	54.85	50.56	45.42	45.39	50.42
Magnesia, Mg O	0 28	0.28	3.70	8.21	8.28	3.96
Manganese oxide (Calc. as Mn O)	-------	0.08	-------	-------	-------	Trace
Phosphoric acid	-------	-------	Trace	Trace	-------	-------
Totals	100.02	100.11	99 92	99.99	100.06	100.10

PROBABLE COMBINATIONS.

Water	0.16	0.30	0.21	0.23	0.18	0.16
Calcium carbonate, $CaCo_3$	98.30	97.95	90.28	81.11	81.05	90.04
Magnesium carbonate, $MgCo_3$	0.59	0.38	7.77	17.24	17.39	8 08
Silica and silicates / Alumina, iron, oxide, etc.	0.95	1.37	1.74	1 42	1.38	1.72
Totals	100.00	100.00	100.00	100.00	100.00	100.00

CORRICK QUARRY.

(TP. 84 N., R. XVII W., SEC. 7, NW. QR. NW. ¼.)

This quarry is operated intermittently to supply the local demand. The layers worked correspond to the upper oölite at Quarry and are only used for foundation work and rough masonry in the immediate vicinity. Some quarrying has been done on section 36, Nw. qr., Ne. ¼, of the same township and range. About eight feet of rubbly limestone rests upon the upper oölitic layers. The section here exposed bears a very close similarity to the beds exposed at Rockton.

The upper layers of the Le Grand beds have been worked to some extent at different times on South Timber creek near Ferguson, on Little Asher creek, Tp. 85 N., R. XVIII W., Sec. 24, and northwest of Liscomb on the Iowa river. In all

cases the stone was for local consumption, and then only for the roughest grades of masonry.

SAINT LOUIS LIMESTONE.

CHAPIN QUARRY.

James Spear operates a quarry on land owned by O. B. Chapin of Union. The stone produced is a close textured, ash-gray limestone, which exhibits a hackly fracture and contains small siliceous concretions, with little iron pyrites in streaks and patches. The quarry is operated only to supply the local demand, but the product is apparently a durable stone.

DES MOINES.

The coal measures in Marshall consist chiefly of shales. A heavy bedded sandstone appears in Timber Creek township, and has been developed to a limited extent. Quarries have been opened on sections 8 and 9, and a considerable quantity of stone suitable for the roughest grade of masonry has been quarried. The sandstone is dark, reddish brown in color, and apparently durable. At present only the upper layers have been explored. The lower layers are more evenly bedded and give promise of a stone suitable for building and trimming.

Clay Industries.

The Paleozoic strata afford little material which is available for the manufacture of clay products. The Hannibal shales of the Kinderhook are too deeply covered to be utilized in this region, while the argillaceous layers exposed at Marshalltown are of doubtful utility. The latter deposits were tested experimentally a few years ago. A sample of the yellow-gray argillaceous marl was made into brick. The color of the burned article was not very different from that of the raw material, and when subjected to the heat given brick for paving streets, no shrinking nor altering of shape was perceptible, and to all appearance there was an entire absence of fusion. On the other hand the pavers were

completely vitrified on certain of the faces. It was hoped that the experiment would prove the manufacture of paving brick possible, but the burned article was left porous and too soft for such a purpose. The manufacture of superior fire brick is demonstrated as a possibility, but the limited extent of the deposit renders its profitable utilization doubtful. The coal measure shales are almost wholly concealed by the glacial debris, and no deposits of economic importance are known within the confines of the county.

In striking contrast to the limited supply of raw material accessible in the Carboniferous series, the Pleistocene deposits are wholly inexhaustible. As has been said the Pleistocene covers the entire county and at nearly every point in such quantity and character as to enable a brick factory to be founded thereon. The material utilized at the present time belongs wholly to the loessial type.

The loess of Marshall county is ordinarily of the common variety. It has a maximum thickness of not less than twenty or twenty-five feet. Certain areas are exceptionally siliceous, and when dry appear as beds of loose sand. The clays are suitable for the manufacture of drain tile, for making common brick by any method, and for making stock and ornamental brick by the dry-press method. The products always have an excellent color and when properly burned their porosity is not so great as to be objectionable. At present clay manufactories are in operation at not less than six localities.

MARSHALLTOWN.

Anson Company Brick & Tile Works.—This is one of the largest plants of the county. It is situated in the southern part of the city, where operations were begun nearly fifteen years ago. It has grown from a small hand yard to a factory with a large output of both common brick and drain tile. A Penfield, No. 15 D with the corrugated crusher, has been used for several seasons. The crusher is required only for the dry clay. Closed sheds are used for drying the product, and

three large clamp kilns for burning. This latter process takes up nearly two weeks. Common brick and tile from 3's to 8's constitute the output. Some loss is experienced through checking which takes place upon the evaporation of the uncombined water.

Sieg & Size operate two yards, one about two and the other about one mile west of Marshalltown, near the Iowa Central track. The one on the south side began operation about forty years ago. The material at each yard is typical loess in a bank from six to twenty-five feet deep; clayey in upper part but more argillaceous below. Certain sections of the the formation in the vicinity are too sandy for brick making purposes. At the south pit the fine sands and silts are beautifully interstratified. An Eagle soft-mud machine is in use at each plant. The brick are dried on pallets in roofed sheds, and no checking occurs if the proper mixture of materials is secured. Three clamp kilns with a total capacity of 200,000 brick are employed for burning. This process takes up only eight days. In addition to these two plants the firm has also a hand yard which is operated in case of an unusual demand.

The G. H. Kohr brick and tile yard is just east of the city limits on the lowland. The raw material, consisting of rather strong modified loess, is treated by a Brewer machine. The newly moulded ware is placed in a closed dry-shed, and little or no checking occurs. Only a single clamp kiln is in use.

MELBOURNE.

The Wulke Factory is located at the crossing of the railroads. There are seven feet of yellow, overlying one-third as much gray, short loess, while a two inch band of ochre separates the two colors. The total thickness of the formation is twelve feet, and under it is blue drift clay. The raw material is drawn up to and run through the pug-mill, then through an auger of the Decatur Leader manufacture and moulded by a machine of the same make. Closed sheds heated with exhaust steam enable drying of the product to be carried on quite

successfully. Three down-draft kilns serve to hold the tile, and the brick are burned in cased kilns. The character of both kinds of the output is very creditable.

RHODES.

A. Harmon now operates a brick plant for the production of brick and drain tile along the right of way of the Chicago, Milwaukee & St. Paul railway. Loess to a depth of ten feet is taken and treated by a "Plymouth" machine. The lower portion of the section utilized is of a bluish color, followed by ocherous layers and finally grading upward into typical loess. Fossils are abundant throughout, but loess concretions are absent, although limey patches may be observed near the base. The color of the well burned product is a cherry red. Considerable loss is sustained through checking. The burning capacity is limited to two small round kilns.

BROMLEY.

Just south of the station at this point is the plant of the Bromley Brick and Tile works. An H. Brewer machine is in operation. The clay is run through the mill, afterwards placed in sheds tightly closed until the mud becomes "set;" otherwise much loss is occasioned through checking. The kiln capacity is 43,000 three-inch tile. Burning can be accomplished in four days. The loess comes from the top of the gradual slope about a half mile south of the railroad. At the bank the top soil is removed and the clay is used to a depth of six feet, below which it becames too sandy. Lower on the slope the character of the formation is decidedly different and is almost entirely sand.

GILMAN.

The Gilman Brick and Tile Works is a new plant situated in the extreme southeast corner of Marshall county and has a large territory adjacent to furnish a market for the products. The raw material is nothing more than modified prairie loess

taken to a depth of several feet. It is strong and the moisture is freed with some difficulty, necessitating artificial heat. A two story shed has been erected, and before long the equipment of the plant will be quite adequate for a large business.

Small plants have been operated intermittently in the vicinity of State Center and Quarry. Hand made brick is the sole product.

Lime.

About a quarter of a century ago lime-burning was carried on to a limited extent. The oölitic beds were chiefly used for this purpose and the manufactured product was of acceptable quality. As transportation facilities improved, lime produced from the older Paleozoic rocks sharpened the competition to such an extent that the manufacture of lime in Marshall county was abandoned.

Building Sand.

The sand flats along the Iowa river between Marshalltown and Albion, and the sand bars in the principal streams, furnish an inexhaustible supply of good building sand. The sub-loessial sands are widely distributed over the county and often attain a considerable thickness. At Marshalltown there are five to ten feet of siliceous material at the base of the loess. The southwestern half of the county is deeply covered with loess and drift, but it is meagerly supplied with the more arenaceous deposits.

Moulding sands.—The sub-loessial layers afford an abundance of material suitable for moulder's use.

Road Materials.

Outliers of the Kinderhook in the eastern portion of the county furnish an abundance of road materials. The larger stream channels afford large quanties of sand and gravel suitable for road work. In the western half of the county materials for the improvement of the roads are almost entirely wanting.

Coal.

Marshall is one of the marginal counties of the Iowa coal field. The coal measures occupy one-half of the district, underlying the western and southwestern portion especially. The coal pockets also doubtless occur in different parts of the area. The records from a number of wells in southwestern Vienna and northeastern Taylor townships record the presence of coal measure strata in that region which constitute the easternmost outlier of the Des Moines in the county. Four miles southwest of Marshalltown a coal measure sandstone outcrops along the Chicago Great Western railway. In both of these localities coal in economic quantities is not known to be present.

The principal locality where coal has been mined in Marshall county is on the Iowa river at a place called Mormon Ridge, three miles northwest from Albion. (Tp. 88 N., R. XI W., Sec. 34, Sw. qr. Se. ¼.) A shaft fifty feet deep was sunk a few years ago and was known as the Mormon Ridge mine. The coal was three feet in thickness. The sequence of layers is as follows:

	FEET.	INCHES.
6. Sand	20	
5. Clay, light colored	3	
4. Shale, dark colored, fissile	2	
3. Coal	3	
2. Fire clay		4
1. Sandstone, exposed	1	

FIG. 37. Coal at Mormon Ridge mine near Albion.

At one time fourteen men were employed. The shaft was operated but a brief period for the reason that only three feet of shale intervened in the roof between the coal and a thick stratum of water-bearing sand. The water gave so much trouble that the mine was abandoned after being operated

about a year. Not more than 100 tons of coal were taken out. A few years later another company leased the property and attempted to work the coal, but owing to the defective pumps made little progress. This mine has been abandoned.

On the north side of Mormon Ridge, on the northwest quarter of the same section, James Hall* states that a limited amount of coal had been removed previous to his visit in 1857, although the shaft was abandoned at that time. Evidence of former prospect holes may still be seen around the base of the hill, but no exact data concerning the coal measures could be obtained.

In a drill hole put down one mile northwest of the Mormon shaft, on the farm of W. C. Ruddick (Tp. 85, N., R. XIX W., Sec. 28, Sw. qr., Sw. ¼), a bed of black shale with some coal was encountered at a depth of 118 feet. The seam was reported to be several feet in thickness and immediately underlain by a thin layer of fire clay.

Some years ago a shaft was sunk on the farm now owned by Americus Dakin on Minerva creek, five miles west of Bangor (Tp. 89, N., R. XX W., Sec. 9, Se. qr., Se. ¼). Coal was found here, but to what extent is not definitely known.

At the present time Marshall is not a coal producing county. Future prospecting will doubtless reveal isolated pockets of coal of economic importance, but with the data at hand, it is hardly reasonable to expect that coal will be produced in commercial quantities within the limits of the county.

Soils.

Marshall is preëminently an agricultural county and the soils greatly outrank in economic importance all of the other geological formations put together. The soils readily fall into four fairly well defined types. The drift, which is composed of glacial debris; the loess, composed of silt and very fine sand; the drift-loess, a combination of the first two, and the alluvium, an admixture of sand and silt in varying proportions. The origin of the soil types has been discussed

* Geology of Iowa, Vol. I, p. 269, 1858.

already under the various divisions of the Pleistocene. The drift soil is coextensive with the Wisconsin drift sheet. This soil contains a high percentage of clay and in many places the processes of agriculture are handicapped by the large number of small to medium sized bowlders. This type is highly productive when well drained, but cold and heavy when not properly ventilated.

The typical loess soil is confined to the immediate proximity of the larger drainage lines. This type prevails in Linn, Timber Creek and western Le Grand townships. It is subject to excessive wash during rainy seasons, and, unless very sandy, it bakes when drying. In productiveness this soil type ranks lowest.

The drift-loess soil comprises by far the greatest area in Marshall county. It is a happy combination of the soils and fine sands of the loess with the glacial debris of the Iowan and Kansan drift sheets. The drift-loess is an open, porous soil allowing the easy penetration of the most delicate rootlets, yet firm enough to support the most vigorous forage plants. It is easily tilled and is a conservator of moisture. It is to this type that Marshall owes her prestige as an agricultural county.

The alluvium flanks the principal streams, and when not too sandy it compares favorably in productiveness with the drift and drift-loess types. When unprotected by levees large tracts of these lands are subject to periodic inundations.

Water Supply.

The larger water courses furnish an ample water supply to the areas through which they flow. The smaller streams are usually dry through a considerable portion of the summer and autumn months. Shallow wells from 40 to 150 feet in depth have proved adequate for domestic purposes until the recent extended dry period, when it was found necessary, in many cases, to go deeper. At present most of the "stock wells" draw their water supply from the glacial sands and gravels

near the base of the drift or from the sandy layers of the Kinderhook. The older water-bearing horizons of the Paleozoic have not been explored in the region, but the Saint Peter and Saint Croix sandstones may be reached at about 1,300 and 1,800 feet, respectively. At Ames and Boone, the Saint Peter sandstone affords about 10,000 gallons per day, while the Saint Croix yields about 200,000 gallons.

West of Rhodes, just out of the corporation, is an artesian well which yields about 2,000 gallons per hour. The water is slightly mineral and is not utilized at present, save as a wayside watering place. The well is about sixty feet in depth and appears to be wholly in the drift.

The Marshalltown water works draw water from the gravel beds of the Iowa river. The water filters through the river sand and is collected into numerous galleries from which it is pumped. The supply is barely adequate for ordinary purposes, while in cases of fire the Iowa river must be drawn on. As several other large cities in the state obtain their water supply in much the same manner as outlined above, it is deemed fitting to append some of the results obtained from a sanitary study of the water. It is a well known fact that the spread of contagious diseases is often contingent on the source of our potable waters and "sewage contamination" is an altogether too common a phrase in our board of health reports treating of epidemics.

BACTERIALOGICAL STUDY OF THE MARSHALLTOWN WATER SUPPLY.

Prof. L. H. Pammel kindly furnished the following abstract of results. The work was done in a large part under his personal supervision.

Mr. G. L. Steelsmith* made an examination of the Marshalltown water supply during the summer and fall of 1896. Dr. Walter H. Haines, of Chicago, had previously made an examination, the results of which are as follows.

		GERMS PER C C.
No. 1.	Across the river from water works	25
No. 2.	Bunce well	190
No 3.	River water	2,240

* Marshalltown Evening Times-Republican, April 23, 1896.

The statement is here made that the maximum number according to Koch of Berlin, and the Franklands of London, is 100 germs per C. C. The maximum number has, however, sometimes been placed at 1,000, and some authors place the number at 3,000. An absolute fixed standard cannot be made, except that 1,000 germs per C. C. is more nearly the maximum in a large number of our river waters. The quanity of organisms is dependent upon the quantity of organic matter present. The important point in connection with a bacterialogical analysis is the quality rather than the quantity. A single organism of *Bacillus coli-communis* or *B. typhi-abdominalis* is sufficient to indicate sewage contamination.

Mr. Steelsmith's determinations are as follows.

		GERMS PER C. C
No. 1.	June 7th, water from river above mill dam	2,170
No. 2.	June 7th, water from hydrant, Dr Meghill's office	1,800
No. 3.	June 7th, water from pumping station	1,200
No. 4.	June 7th, water from sixteen hydrants, average	1,900
No. 5.	Sept. 9th, water from six hydrants, average	2,040

So far as the number from streams is concerned, the above would not be considered excessive or necessarily injurious, since water taken from the Croton reservoir, New York, contained 5,000 to 15,000 germs per C. C.; water from the Spree, which furnishes Berlin with water, contains, according to Frankel, 6,140 germs per C. C.; but this number increased to over 245,000 below the city. Water from the Mississippi at La Crosse, Wisconsin, during the spring months contained 3,000 germs per C. C. In all streams there are extraordinary fluctuations so far as quantity is concerned. These fluctuations are due to the amount of soil carried from the surrounding country. The great number found in the Iowa river last summer must be associated with the frequent rains. Numerous investigators have shown that during the autumn and winter, germs are far less numerous than during the spring and summer months, and yet the former seasons are the periods of most frequent occurence of typhoid fever.

Of the germs found in the hydrant water of Marshalltown, but one was regarded as suspicious. It agreed quite closely with the morphological and physiological characters given for *Bacillus coli-communis* and proved to be pathogenic for rabbits. The relation of this organism to sewage contamination can no longer be questioned, as this Bacillus is an inhabitant of the human intestines and it is only natural that it should find its way to the river.

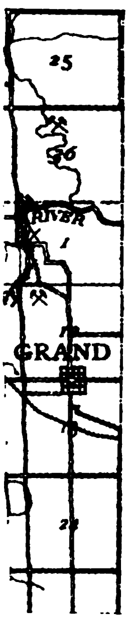
The results of this investigation go to show that the water which has filtered through the river sands is safe and wholesome, but that the water drawn from the river direct may be at the peril of the public health.

Water Power.

The Iowa river furnishes an abundance of water power, the average gradient being about three feet per mile and the flow fairly constant. Flouring mills are in active operation at Albion, Marshalltown and Le Grand respectively. A head of six feet is obtained at Albion and six and one-half feet at each of the other two localities. All of the mills can be run on full time and at full capacity save during periods of very high or very low water. From fifty to eighty horse power is available at each point. The flow of water in the smaller streams is too small and inconstant to merit attention in this connection. Mills of small capacity on Timber creek were formerly operated intermittently. None are active at the present time.

ACKNOWLEDGMENTS.

In the preparation of the present report the representative of the survey received much encouragement and friendly assistance from many citizens of the county. Thanks are especially due to Dr. W. S. McBride of Marshalltown, and the officials of the Le Grand Quarry Co., who have been untiring in their efforts to facilitate the investigation. The notes of Mr. E. H. Lonsdale on the clay industry have been used freely, and the writer has been the recipient of many courtesies from the different members of the Survey.



S.W. BEYER.
1897.

LEGEND

GEOLOGICAL FORMATIONS

DES MOINES.

GEOLOGY OF POLK COUNTY.

BY

H. F. BAIN.

GEOLOGY OF POLK COUNTY.

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CONTENTS.

INTRODUCTION.

LOCATION AND AREA.

The country to be described in this report is of interest to the layman as containing the capital city of the state and to the geologist as being located at the apex of the Des Moines lobe of the Wisconsin ice sheet. It lies slightly southwest of the center of the state and is bounded by Boone and Story counties on the north, Jasper and Marion on the east, Warren on the south and Dallas on the west. Of these regions Boone and Warren counties have been previously described by Dr. S. W. Beyer* and Prof. J. L. Tilton† respectively. Polk county is the meeting place of the formations described in these reports. The county includes the usual sixteen congressional townships with 586 square miles; an area divided into twenty civil townships as shown upon the accompanying map.

Physiographically, it lies mainly in the valley of the Des Moines river and within its limits the Raccoon joins the latter stream. The northeastern portion of the area belongs to the valley of the Skunk river and that of its tributary, Indian creek.

PREVIOUS GEOLOGICAL WORK.

The early establishment of a military post at the juncture of the Des Moines and Raccoon rivers led to the region being visited from time to time by various geologists in the employ of the national government. Many of these expeditions were more especially directed to the accomplishment of geographical or military purposes. Such was that led from the fort to the source of the Des Moines river by Capt. J. Allen‡ in 1844, though the incidental topographic and geological notes given in the account of this expedition are very suggestive.

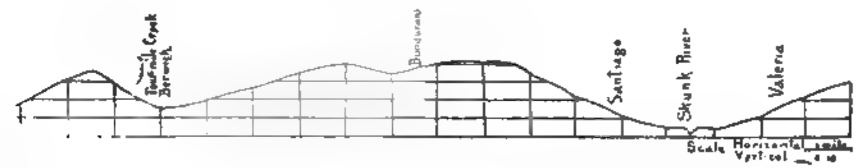
Information more directly geological may be obtained from the report of the expedition of J. N. Nicollet.§ In it is

*Iowa Geol. Survey, vol. V., pp. 175-239.

†Ibid., 301-359.

‡Ex. Doc., House of Rep., 29th Cong., 1st Sess., No. 168, 18 pp. Washington, 1845-46.

§Sen. Doc., 26th Cong., 2d Sess., V., pt. 11, No. 237. Washington, 1841.



...nd showing the upland. The width of the valleys

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given a list of fossils collected from the Des Moines river above the Raccoon fork by Lieut. Fremont. Knowledge of the stratigraphy of the region began with the explorations of Dr. D. D. Owen, carried on in the summer of 1849. In his trip up the Des Moines river* he located and described the principal exposures, recognizing the presence of coal measures, drift and loess.

Worthen† in 1856 visited Des Moines and noted some of the exposures near the city.

In the course of the work of the White survey the county was visited by both Mr. St. John and Dr. White,‡ though no detailed survey of the county was made. The drift deposits within the county have been since written upon by Call,§ McGee and Call,‖ and Keyes and Call,¶ while Keyes has made extensive studies of the coal measures and of the paleontology. The latter has published numerous papers upon the region, the more important being referred to in the following pages. His studies upon the coal have been summed up in his general report upon the coal deposits of the state.**

PHYSIOGRAPHY.

TOPOGRAPHY.

Polk county is not a region of strong contrasts. Topographically the region belongs to the type called "prairie plain" by Powell.†† In a broad way it may be conceived to be an essentially even plain cut into by river channels. The evenness of the upland surface can never be lost sight of, and from any high point in the county one can see the surrounding region rising to the same general level. There are no points of greater altitude and the divides all belong to this

*See Geol. Surv. Wis,. Iowa and Minn., pp. 121-123, with plates. Philadelphia, 1852.

†Geol. Iowa (Hall), vol. I, pt. 1, 170-172. Albany, 1858.

‡First and Sec. Ann. Rep. State Geolgist, pp. 167-176. Des Moines, 1870. Geol. Iowa, vol. II. pp. 261-262. Des Moines, 1870.

§Amer. Nat., XV, 782-784. 1881.

‖Amer. Jour. Sci., (3), XXIV, 202, 223. 1882.

¶Proc. Iowa Acad. Sci., 1890-1891, 30. 1892.

**Iowa Geol. Surv., vol. II, pp. 267-294. Des Moines, 1894.

††Nat. Geol. Mon., vol. I, No. 3, p. 68. New York, 1895.

general plain. This plain has an altitude at Bondurant of 975 feet, at Mitchellville of 976, at Altoona 966, at Orilla 975, at Ankeny 1,005, and at many other points occurs at the same general level. Into this plain the rivers have cut channels to various depths. The Skunk at Santiago is about 175 feet below the high land on each side. The Des Moines river has cut from fifteen to twenty-five feet deeper. The minor streams have cut to various depths, depending on their size and the distance from the main stream.

When one examines the topography in greater detail, certain differences are noted which at once separate the region into two portions, between which the contrasts are as sharp, as constant and as multitudinous as those between an alluvial valley and the adjacent uplands. To the sympathetic student of land forms, these contrasts of topography are as definite and as full of meaning as are the contrasts in fossils obtained from different formations. The line separating the two areas is marked upon the map of the superficial deposits as the northern border of the loess, and runs approximately from south of Nobleton through Rising Sun, around the nose of Four Mile ridge, across Capitol and West hills, just north of Valley Junction and between Commerce and Ashawa. The region north of this line has had a different history from that which lies south of it, a history differing in the length of the erosion period and hence shown in the character of the streams; a history differing in origin of the surface material and hence reflected in the landscape. North of

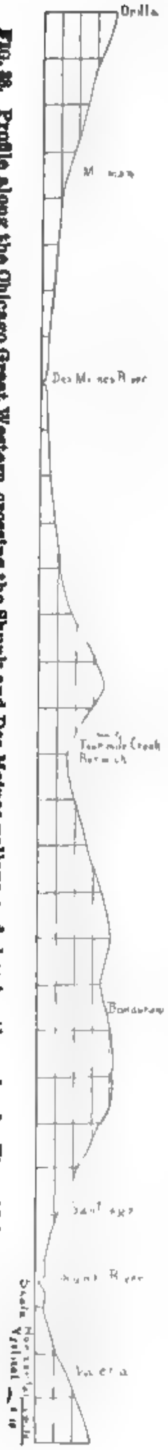


FIG. 38. Profile along the Chicago Great Western crossing the Skunk and Des Moines valleys and showing the upland. The width of the valleys is much exaggerated owing to the direction of the section.

the line the general appearance of the country differs radically from that south of it despite the fact that the surface as a whole rises to the same plane and the surface material is in each case loose detritus. The contrasts are not always so sharply preserved along the border, and yet, on the whole, one is constantly struck by their presence rather than by their absence. There are few places where the contrasts between the two drift sheets are so excellently shown and so readily studied as at Des Moines.

NORTHERN AREA.

In the northern portion of the county the prevailing landscape is flat. The divides are broad and have practically no slope. This is well shown in crossing the divide between Four Mile creek and the Skunk river. In the region near Bondurant is a broad even surface of immature drainage. Only the faintest contrasts in elevation are noticeable. The same type of upland is shown between Mitchellville and Altoona and may be readily examined in its most typical aspect near Ankeny. As seen at the latter point especially, the presence of swales and inter-swales is quite striking. It gives a topography which may be called a saucer topography, since the low circular, grass-grown and often water-holding swales are similar in outline and cross-section to shallow saucer-like depressions. The higher portions of land between the swales are almost the exact reverse of the latter; being low, very gently rounded hummocks. The swales vary in diameter from mere depressions a dozen feet across to well defined basins, often holding ponds and, in regions a little farther north, small lakes. Over such a surface there are no drainage lines. Many, indeed most of the ponds, have no outlets.

While the saucer topography is characteristic of the region covered by the Wisconsin drift, and indeed is not known to occur south of its limit, other phases occur with it. In the region near Kelsey there is a bit of rather rough country. The hills are of considerable height, irregular form, and are

independent of the streamways. The drainage conforms to the hills rather than forms them. Drift seems to be the materials which make up these ridges. It is somewhat sandy and full of gravel in the upper portion and seems to indicate a certain amount of water action. The general aspect of the hills is morainic. Their nature will be described more in detail in another portion of the report.

In the northern portion of the county the valleys are, as a rule, narrow. In certain cases they are broad though the streams are unimportant and narrow. In such instances the stream has usually a narrow recent valley, with a very moderate development of alluvium, winding through the older larger valley. The broad bottoms of such a valley, for example that of the Beaver, is covered by irregularly disposed hills of sand, gravel and till in its less typical phases. These hills are low, very gently rounded and often merge into almost terrace-like forms. The boundary of such a broad valley is ordinarily imperfectly defined. The slopes rise with increasing steepness until they meet the upland plain. The whole represents rather a long, broad, fairly shallow sag in the surface of the latter. An excellent example of such a sag may be seen just north of Highland Park or North Hill, and separating the latter from the main upland plain upon which Saylor station is located.

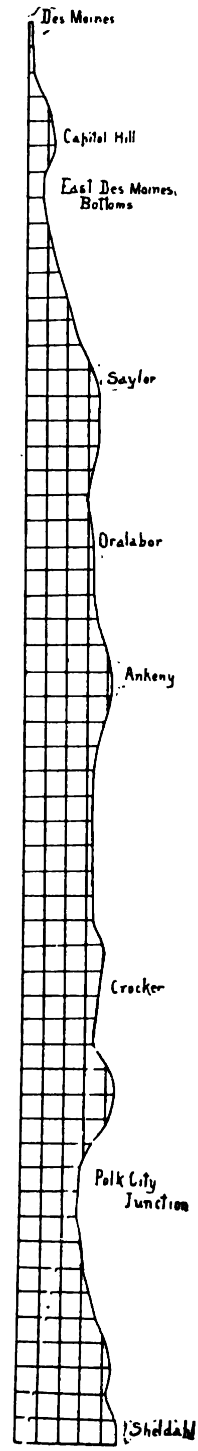


FIG. 39. Profile along the Chicago & North-Western railway from Des Moines to Sheldahl. The section starts on the Des Moines bottom land, crosses Capitol Hill at a low point, traverses the old valley of the Des Moines and from Saylor runs over the upland. Scale: Horizontal, ½ mile; vertical, 250 feet.

It takes but little observation to satisfy one that in this northern portion of the county the topography was not formed by the present streams, and is, in fact, not a normal erosion topography. There is no constant relation between the size of the stream and its valley. There are areas of rough, hilly topography where the streams wander in and out in aimless fashion. In such regions especially, and the same is true for the region in general, the streams have no flood plains or such as are only very slightly developed. The land forms also exhibit anomalous curves which are not characteristic of stream erosion. In short, the land forms are glacial and the country is in extreme youth. The stream action has only just begun. The upland plain is barely cut into. It is crossed rather than dissected by the streams, and the latter have merely cut gashes in its surface.

SOUTHERN AREA.

South of the dividing line mentioned, a very different topography is encountered. The surface material is still drift. The land forms are, however, erosion forms. The saucer topography of the northern upland and the hummocky topography noted near Kelsy have disappeared. The inter-stream divides rise to an even surface which is, in a general way, level. There are flat-topped divides but these are relatively narrow. The plain is thoroughly dissected and the drainage is in early maturity. Much, however, of the upland is yet unreduced and not all of the streams have ceased to cut down and begun to fill up: The landscape accordingly marks an intermediate stage in which the surface is largely reduced to slope.

The region is crossed from west to east by the broad valley occupied in part by the Raccoon river and in part by the Des Moines river. Numerous tributary streams subdivide the area. The larger of these streams, for example Camp creek, simulate the master streams in having definitely marked alluvial bottom lands. Indeed all the streams of the southern area have developed alluvial plains of greater or less extent.

Alluvium is found along the lower courses of even the smaller creeks. If, for example, one examines West Four Mile he finds at its embouchere upon the bottom land of the Raccoon a rather definite flood plain which may be traced up the stream some little distance. In passing up stream it becomes narrower, takes on more and more slope, and thus by degrees merges into the side slopes. At a certain stage it is difficult to separate the flood plain from the slope. A little farther on the flood plain has altogether disappeared, the change being almost imperceptible.

It is interesting to contrast this with the change which the flood plain undergoes in the case of those streams which start upon the Wisconsin drift and flow down upon the Kansan. In such cases the alluvial plain, which is broad in the lower portions of the valley, narrows up at once when the stream is traced back over the later drift border. This is shown in the case of East Four Mile creek and is also marked on Spring, Mud, and Camp creeks. The development of alluvium along a river is indicative of considerable stability and a long time of work. New streams rarely have flood plains. Old ones usually do. The inference, then, is that the upper courses of the streams mentioned are much younger than the lower courses. That the disappearance of the flood plain along East Four Mile is not due to the same causes that have obtained in the case of West Four Mile is shown by the fact that in the former it is abrupt; in the latter it is gradual. The land forms of the southern area, then, are the results of stream action. They have required a long time for their development; a longer time than that necessary for the development of the northern landscape. The measure of this time and the details of the contrast between the two areas may well be noted in connection with the description of the individual streams.

DRAINAGE.

The streams of Polk county belong to two systems, the Skunk and the Des Moines. By far the larger portion of the

county is drained by the latter river and its tributaries. Within the county the valley of the Des Moines is separated into two sharply contrasted portions lying respectively above and below the mouth of the Raccoon river. The upper valley is narrow, steep-sided and very recent. The lower is broad, has a well developed flood plain, usually well rounded sides, and in fact shows all the marks of an ancient stream. That portion of the course lying between the mouth of Daily's run and the Raccoon river is intermediate in age, though in topography it more closely resembles that along the upper reaches of the river. The Des Moines river is a stream of consider-

FIG. 40. Des Moines valley, older portion, below Hastie. The bluff at the right shows loess over Kansan drift.

able magnitude; so much so that in early days it was traversed by small Mississippi river steamboats as far as the mouth of the Raccoon and even beyond. The bottom land below the forks is, as is shown upon the accompanying map, from three to four miles wide. Its borders are usually well marked, the hills rising abruptly from 100 to 135 feet above the flood plain. There is a slight farther rise until the land reaches a general altitude of about 160 feet above the river. In this portion of its course most of its tributary streams flow in from the north.

They include East Four Mile, Spring, Mud, and Camp creeks, all of which have already been partially described. East Four Mile creek is a long stream with a narrow valley. It has no tributaries of any great length and few that are branching. Practically all of its course is upon the later drift. The last two miles is across the flood plain of the Des Moines, and the mile just above is through a relatively broad and well marked valley which is of preglacial origin. The upper course is a mere trench across the drift and seems to be of no great age.

Spring and Mud creeks have their sources just within the border of the upper drift in poorly defined valleys. Below the border they follow well marked valleys and receive numerous small branching tributaries. Camp creek has its source upon the drift plain between Altoona and Mitchellville and flows south, reaching the Des Moines just outside of Polk county. It receives few tributaries though it is a stream of some size and age. From the south the Des Moines receives a few small streams of which Yader creek, itself an insignificant branch, is the larger. The streams, including West Four Mile and Elm branch, which flow into the Raccoon river from the south, are also of small size. The reason for this seems to be that North river, which joins the Des Moines just below Avon, has preempted the territory which might have been drained by Yader, Four Mile and Elm branches. North river empties into the Des Moines below these streams and hence has a lower outlet. It is an older stream and in the struggle for territory has succeeded in capturing by far the larger portion of the area between it and the Raccoon-Des Moines valley.

In the intermediate portion of its course the Des Moines river flows through a narrow valley flanked by high bluffs mainly composed of coal measure strata capped by loess and Wisconsin drift. The valley sides are veneered with loess, and hence this channel is of interglacial and possibly of preglacial age. The river in this part receives no tributaries of any consequence. At the upper end of the narrow portion

there is a broad expansion of the valley marked by a wide alluvial tract extending from Highland Park to Saylorville. Within this portion of its course the river receives Beaver creek from the west and Saylor creek and Daily's run from the east. The two latter are very small streams which do not have well marked valleys. Saylor creek, after coming out from the drift covered region, crosses the alluvial bottom land in a shallow ditch-like channel two miles or more long, following close along the eastern edge of the bottom land.

Above Saylorville the Des Moines valley narrows rapidly and for a considerable distance parallels the broader valley now occupied by the Beaver. The relative width of the two is shown upon the map. The Ridgedale ridge is usually narrow. It slopes very abruptly down to the Des Moines river, which is bounded on the east by equally abrupt slopes. On the west the ridge normally slopes down to the Beaver with a regular, gentle inclination. This is not however always true. In sections 36, 25 and 26 of Tp. 80 N., R. XXV W., the slope is quite as abrupt as in the opposite direction. This abrupt slope towards the Beaver is however exceptional. The river receives in this portion of its course Rock, Big and Mosquito creeks, all from the east. Big creek is the largest stream, but though it carries considerable water, it has only a narrow valley and a narrower strip of irregularly developed alluvium.

The Raccoon river flows into the Des Moines from the southwest. It has a marked valley, with a well developed flood plain. Its tributaries from the south are small but evidently old. From the north it receives Jordan branch, a recent stream flowing down from near Ashawa, and Walnut creek, which flows in east of Valley Junction. Walnut creek is rather well developed and has through a considerable portion of its course a definite flood plain. It does not seem however to be an old stream.

The Skunk river system does not drain an important portion of the county. The main stream enters the county about eight miles west of the northeast corner, flows

southeast and leaves the area ten miles south of the same point. It flows in a broad flat-bottomed valley bounded by low rounded sides. The valley is evidently of considerable age, though the present river has only insignificant tributaries. It receives White Oak creek, Swan, and Byers branches from the west but no streams of name from the east. The branches drain a strip parallel to the main stream and less than four miles wide. Indian creek, which flows across the extreme northeastern corner of the county parallel to the Skunk and about five miles distant, joins the latter stream near Colfax. Within the area now being considered it is wholly independent of the Skunk and flows in a valley which is a smaller homologue of that of the parent stream.

HISTORY OF THE DRAINAGE.

The main outlines of the drainage of Polk county were evidently developed in preglacial time. The Des Moines, the Raccoon, North river, East Four Mile, the Skunk and Indian creek evidently run in valleys which are, in part at least, preglacial. The origin of these rivers was due to causes antecedent to the glacial period. Their preglacial valleys, as we know them, seem not unlikely to have been excavated in the period immediately preceding the advent of the ice. Their deeper channels are cut in a moderately flat rock surface which probably represents a Tertiary, or later, base-level. The channels are most probably the result of the post-Lafayette emergence.* That the streams had before this been developed, and by the post-Lafayette emergence were merely revived, is altogether probable, but this, and indeed all except the fact of the existence of certain of the channels before the ice came, lies largely in the domain of hypothesis and is, at present at least, not susceptible of field demonstration. The lower course of the Des Moines river, that below the mouth of the Raccoon, has been filled in with drift to a considerable depth. The shaft of the Gibson mine No. 1, located on the edge of the bottom land, passed through fifty-six feet

*McGee, Twelfth Ann. Rept. U. S. Geol. Surv., pt. 1, p. 515. 1891.

of drift. The Hastie mine working at a depth of 100 feet below the river was much interfered with by water. Wells driven down upon the plain at Avon pass to considerable depths without encountering rock. The hills, however, contain rock at levels considerably above the water level. Good sections and rock exposures are common wherever there has been recent cutting. This is not, however, true in all cases. Usually the drift alone is seen and at points the recent cutting of the river against its sides shows only the undisturbed

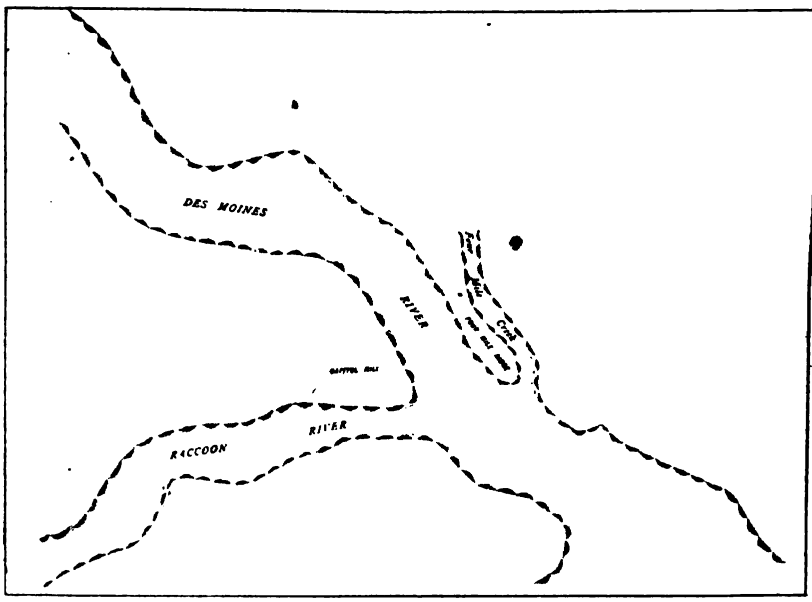


FIG. 41. Preglacial drainage at Des Moines.

drift down to water level. The valley in this portion seems then to have been formerly deeper and perhaps slightly wider; at least its present form is not its original form. The material which fills in this older valley is the Kansan drift and loess, and will be described later.

In that portion of the old valley which lies between Capitol Hill and Four Mile Ridge it has been found impossible to mine a bed of coal which lies about ninety to one hundred feet below the river level, because the overlying slate roof is so thin that it crushes in and fills the mine with drift and water. In the

Giant mine, located on the western edge of this plain, at a depth of about 100 feet, a preglacial drift filled valley was encountered*. Similar channels have been encountered by other mines located at the edge of this plain. The rock rises in Capitol Hill to a height of seventy-three feet above the plain which is itself about twenty feet above the water of the river. On the crest of North Hill, or in Highland Park, sandstone belonging to the coal measures is encountered at a depth of twenty-five feet. On the low land between Highland Park and Saylor station wells go through seventy-five to 100 feet of drift. The Poor Farm well, 140 feet above this bottom land, only passes through eighty feet of drift, which is perhaps an unusual depth, as rock is found in the same region at depths of fifty feet and less. On the high land near the Union mine the rock is encountered at about twenty feet. The nose of Four Mile Ridge is made up largely, to a depth of 116 feet or more, of loose material, and yet it has a core of coal measures, as has been proven by recent drilling in Grandview park. There is then here a drift filled valley with rock-bound sides. The filling material is, in part at least, Kansan drift.

The Beaver valley shows topograpic characteristics similar to those of the old valley just described. Its width is comparable to that of the latter valley, and if to it be added the width of the narrow valley occupied by the upper course of the Des Moines the sum is about equal to the width of the Des Moines below the mouth of the Raccoon. The bottom of the Beaver valley is covered by the modified Wisconsin drift. Wells in this bottom land do not reach rock at depths of fifty feet. The side slopes show rare rock exposures, though the coal measures rise in them to heights considerably above the stream. At points undisturbed Kansan drift is found low down in the valley.

There is then a broad preglacial valley running across the county, now occupied in part by the Beaver, in part by the Des Moines and in part unoccupied. For reasons to be con-

*Keyes: Iowa Geog. Surv., II, 183. 1894.

NATURE OF STRATA.	THICKNESS.	DEPTH.
[illegible] and shale, gypsum gray and [illegible] flakes, shale green, perhaps [illegible] above	15	1223
[illegible]stone, light blue, gray, highly sel[illegible]iferous, with some flakes of gypsum	145	1368
[illegible], cherty, arenaceous, grains [illegible] and minutely rounded, much [illegible] rounded fragments, perhaps [illegible] above	22	1390
[illegible], crystalline, granular, [illegible] chert and some chalce[illegible] samples	55	1445
[illegible] fragments, purplish [illegible] non-calcareous, [illegible] gray	33	1478
[illegible] gray powder, [illegible]	[illegible]	1738
[illegible] and brown, [illegible] residue finely [illegible]	[illegible]	1938
[illegible] calcareous	[illegible]	1946
[illegible]	30	1976
[illegible]	10	1986
[illegible]	[illegible]	2025
[illegible]	7	2032
[illegible]	30	2062
[illegible]	23	2085
[illegible]	5	2090
[illegible]	5	2095
[illegible]	5	2100
[illegible]	4	2140
[illegible] gray [illegible]	8	[illegible]
[illegible]	6	[illegible]
[illegible]	10	[illegible]

oped which later played an important part in changing the course of the Des Moines river. The first was a tributary of the Raccoon and ate its way back by headwater erosion along the line now occupied by the Des Moines from Thompsons bend to its mouth. The second, *b*, was tributary to the Des Moines as it then was, and worked back toward the south along the line now occupied by the Des Moines river from the mouth of Dailys run to Crocker park. These streams cut back farther and farther, *a* encroaching upon *b* until the valleys were continuous. Possibly *a* captured *b* and a portion of the Des Moines was diverted to the new course. More probably the valley was not cut to that depth, and the Des Moines

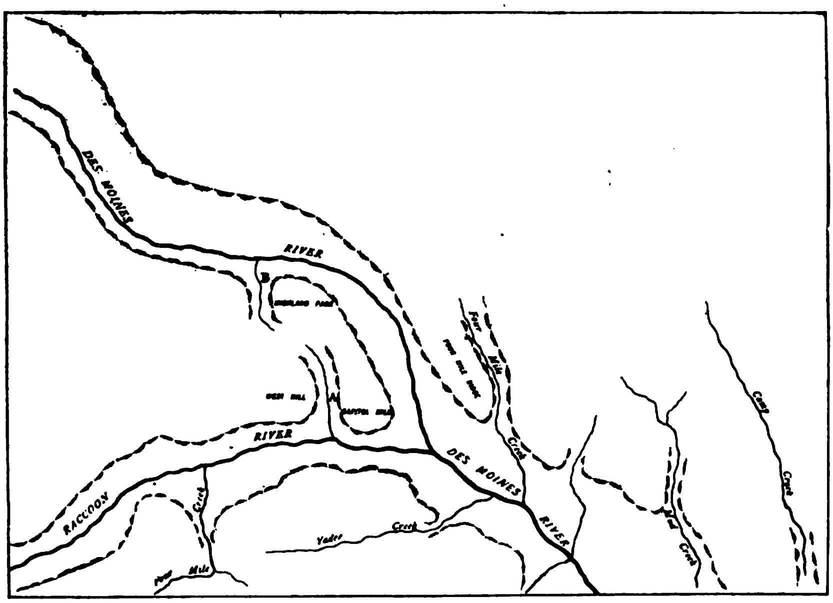


FIG. 42. Pre-Wisconsin drainage near Des Moines.

had not begun to flow through the new channel at the time the loess was deposited. The latter spread in this region in a fairly uniform mantle over the Kansan drift both upon the upland and in the valleys. It did not materially affect the arrangement of the streams though it changed the contours of their side slopes and softened the cross-sections. The

streams began at once to clear out their valleys and were engaged in that work at the advent of the Wisconsin ice.

It is probably legitimate to suppose that the ice advanced in a direction normal to the present limit of Wisconsin drift, and that its advancing front occupied lines successively farther south and parallel to this line of drift limit. Such an advance would have forced the Des Moines, as it then was, over against the southwest side of its valley and would probably have blocked its course between Saylorville and Dailys run before the upper portion of the stream was thrown entirely

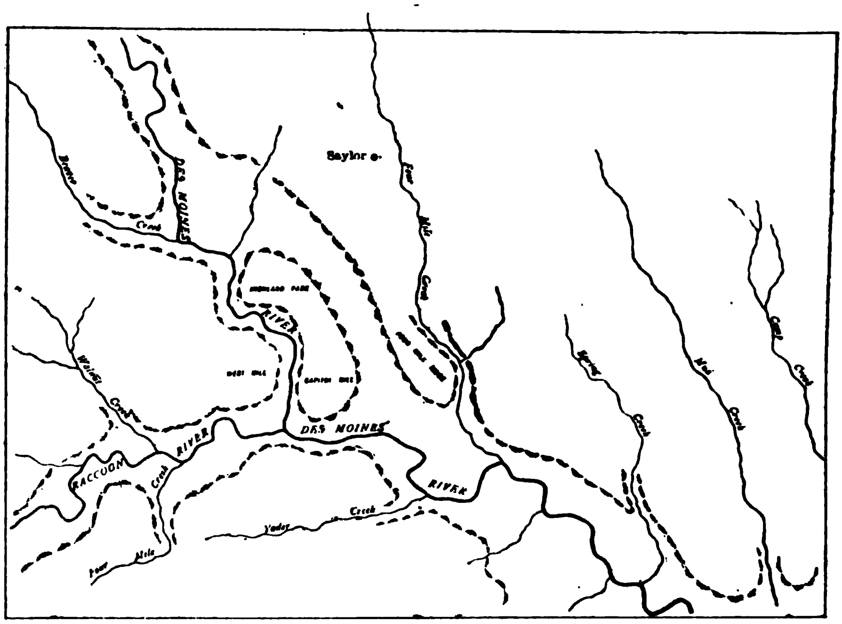


FIG. 43. Present drainage near Des Moines.

out of its valley. The waters of the upper course, swollen and powerful, seeking an outlet, flowed up the stream *b*, across the low divide, and through *a* into the Raccoon. The ice advanced but a short distance beyond before coming to its final halt, and it is not impossible that the stream held its course under the ice for a considerable portion at least of this time. As the ice melted back the river held to the new course and abandoned the old one.

With the continued retreat of the ice certain other rearrangements took place in the streams. The Des Moines abandoned its upper valley, now occupied by the Beaver, and cut the newer and narrower channel in which it now flows. The reasons for this change are obscure and no satisfactory explanation can now be given. But little is known of the course of the older channel except in Polk county. In Guthrie county situated to the southwest, there are three streams, Middle Raccoon, Brushy Fork, and South Raccoon, which have parallel courses, the general direction being northwest-southeast. These streams are outside the area covered by the Wisconsin ice and were uninfluenced by it. In a general way the master streams of the entire region, where so uninfluenced by later operating causes, flow in the same direction. This is also the direction followed by the old Des Moines valley as far as we know it, and it would seem not unfair to suppose it to be the true direction of the old stream. The upper portion of the Des Moines river, however, has a course much more nearly due south. This is shown much more strikingly above High Bridge than below.

This upper portion of the Des Moines is consequent upon the slope of the surface at the retreat of the Wisconsin ice. The valley was, in a certain sense, formed all at once, not by simple and progressive headwater erosion. This is seen from the fact that on the bluffs opposite Corydon undrained saucer depressions occur almost in sight of the river a hundred feet or more below. It is hardly supposable that a river could by simple headwater erosion cut back half way across the state and yet not have time to invade the territory so near itself and so exposed to attack. The larger portion of the river course must then have been established with great rapidity, and was doubtless an immediate result of the ice melting. It is but natural that a stream which owes its origin to so intimate a connection with the ice should take the same direction that had been taken by the ice lobe itself, and the Des Moines river follows quite closely the median line of the Des

Moines lobe of the glacier. Such a line was bound to make an angle with the older drainage lines and it seems not unnatural that this angle should be at the apex of the lobe, particularly when, as has been explained, the river course had at this point already taken the new direction.

The history of the Skunk river and its tributary Indian creek can not be traced in so great detail. That both these valleys are preglacial and that they are resurrected streams has already been indicated. The noteworthy difference between the Skunk and the Des Moines is that in Polk county the former has a very limited tributary area. It has not, it is true, cut quite so deeply as the Des Moines, but since the tributaries of the two streams have not cut back far enough to interfere, the matter is of but slight significance. The resurrection of the Skunk occurred at the same time that the upper portion of the Des Moines was formed. The Skunk had softer material to work upon, and it also had an established course, so it would be expected to have been the gainer. It, however, follows the old course from northwest to southeast and hence was out of harmony with the new drainage. The major portion of the water ran south and hence the Des Moines, running directly in the course of the new drainage, was favored, while the Skunk was starved. In Hamilton and Story counties the Skunk has taken the new direction and has a corresponding increase in tributary drainage.

TABLE OF ELEVATIONS.

The following table gives the elevation above sea level of the principal towns in Polk county so far as they are available, with a few in adjoining counties which are given for reference.

STATION.	Altitude above sea level.	AUTHORITY.
Altoona	966	C., R. I. & P.
Ankeny	1,005	C. & N.-W.
Ashawa	844	C., R. I. & P.
Avon	740	C, R I. & P.
Berwick	845	C. Gt W.
Bondurant	963	C. Gt. W.
Carbondale	791	Barometer.
Commerce	845	C., R I. & P.
Crocker	995	C. & N.-W.
Cummings	985	C. Gt. W.
Des Moines—		
Low water at mouth of Raccoon	776	
Fourth and Walnut	807	City Engineer.
Capitol avenue and East Eleventh street	888	City Engineer.
Grand avenue and East Seventeenth street	835	City Engineer.
Cottage Grove and Western avenue	969	City Engineer.
Hastie	779	Wabash.
Milliman	830	C. Gt. W.
Mitchellville	976	C, R. I. & P.
Oralabor	975	C. & N.-W.
Polk City Junction	960	C. & N -W.
Runnells	750	Wabash.
Santiago	832	C. Gt W.
Saylor	965	C. & N.-W.
Sheldahl	1,042	C. & N -W.
Tamworth	762	Wabash.
Valley Junction	810	C, R I. & P.

STRATIGRAPHY.

Geological Formations.

GENERAL RELATIONS OF STRATA.

The rocks of Polk county belong to two series of very different character, age and origin. The more obvious surface material consists of a sheet of drift, loess, sand, gravèl and àlluvium which has been spread over, and very largely conceals, the underlying indurated beds, which alone are commonly known as rock. The latter includes the usual coals, shales and sandstones common to the coal measures of the state. The former includes the glacial and river deposits of the Pleistocene. The major physiographic features are due to the coal measures. The flat uplands, the main river divides and many of the minor stream partings are formed of these beds. Exposures of coal measures occur quite generally

along the Des Moines river and throughout the southern portion of the county. The whole area of the county, however, with the exception of the limited outcrops of coal measures, is covered by a heavy mantle of Pleistocene beds which give character to the minor physiographic features.

The taxonomic rank of the formations exposed in the county is shown in the following table.

GROUP.	SYSTEM.	SERIES.	STAGE.	FORMATION.
Cenozoic.	Pleistocene.	Recent.		Alluvium.
		Glacial.	Wisconsin Iowan. Kansan. Aftonian Pre-Kansan.	Drift. Loess. Drift Gravels. Drift.
Paleozoic.	Carboniferous	Upper Carboniferous.	Des Moines	

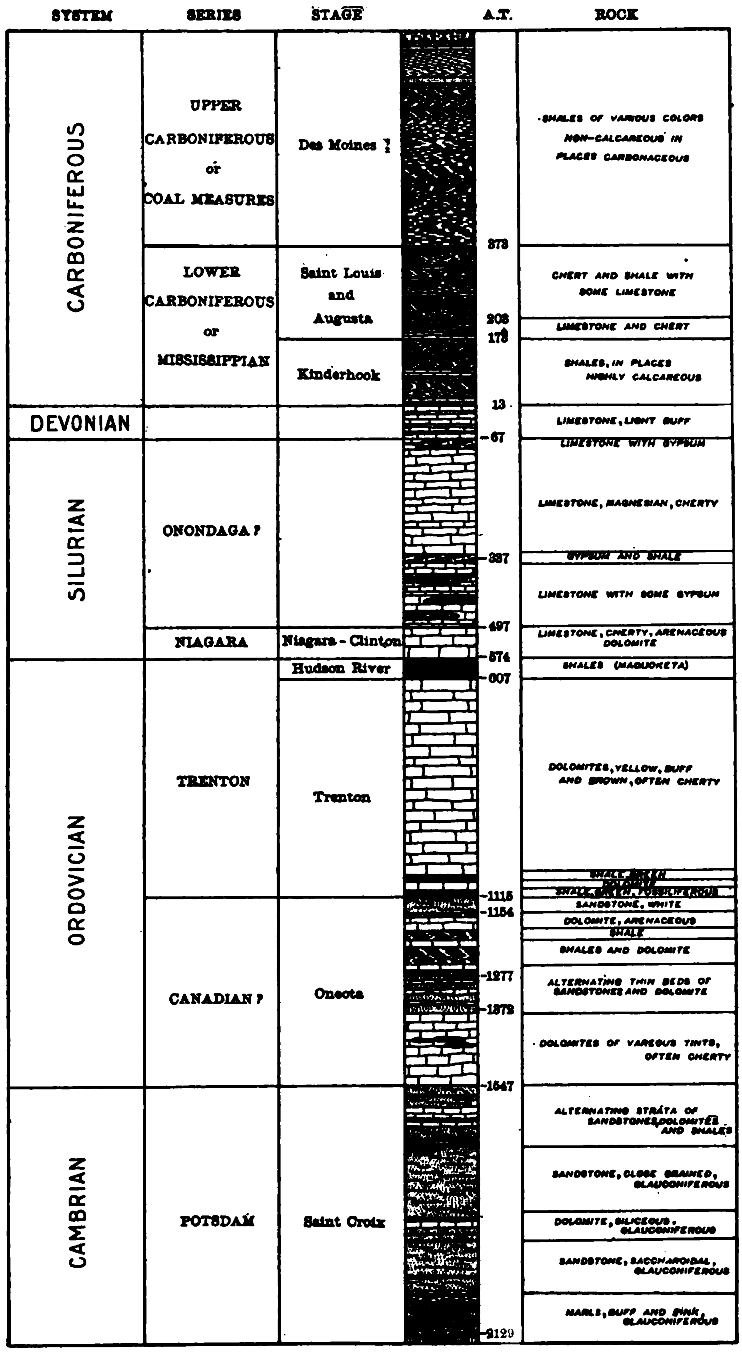
CARBONIFEROUS.

UNDERLYING FORMATIONS.

No formations lower than the coal measures are exposed within the county. The nearest outcrops of the next underlying strata, the Saint Louis limestone, occur in Story county on the north and Marion county to the southeast. The rocks still lower, outcrop in regular sequence to the northeast. Some deep boring has been done within the county so that we know a little of these underlying beds. The Greenwood park well, recently completed, was carried to a depth of 3,000 feet. Samples of the drillings were carefully preserved by Mr. E. Van Hyning and were studied by Prof. W. H. Norton of this survey. The record of this well with Professor Norton's correlations is given below.

GREENWOOD PARK WELL.

	RECORD OF STRATA.	THICKNESS.	DEPTH.
78.	Till, buff, sandy with a few pebbles, non-calcareous	14	14
77.	Shale, black, brittle, carbonaceous	1	15



GREENWOOD PARK (DES MOINES) WELL.

No.	RECORD OF STRATA.	THICKNESS.	DEPTH.
76.	Shale, gray "fossiliferous"	1	16
75.	Shale, black, carbonaceous, calcareous, highly pyritiferous	3	19
74.	Shale, gray	4	23
73.	Shale and limestone, bluish gray, highly fossiliferous	15	38
72.	Shale, varicolored	67	105
71.	Shale, bluish gray, highly and finely arenaceous, hard	10	115
70.	Shale, bluish gray, slightly calcareous	60	175
69.	Shale, dark drab and black, carbonaceous	11	186
68.	Shales, gray, drab and purplish, practically non-calcareous, one foot of gray chert at 284 feet	292	198 (?)
67.	Shale with chert, heavy bed, very hard to drill. The most of the sample is an argillo-calcareous powder of 250°; 34° remain after washing as sand of white chert, flint and limestone. Of this residue 8° are soluble in acid. Of the 216° washed out as powder 62° are soluble in acid. The shale is reported as caving in from above, but its calcareous nature indicates that it is in part interstratified with chert and limestone	170	668
66.	Limestone and chert, brownish gray	30	698
65.	Shale, light blue and gray	40	738
64.	Shale, terra cotta red, highly calcareous	10	748
63.	Shale, light blue, gray	25	773
62.	Shale, light gray, highly calcareous, fine cherty residue	85	858
61.	Limestone, light buff, with much gray chert	80	938
60.	Limestone, light blue, gray, crystalline, saccharoidal, effervescence slow, with considerable white gypsum	20	958
59.	Limestone, cherty, crystalline, blue-gray, effervescence moderately rapid	53	1011
58.	Limestone, cherty, crystalline, saccharoidal, dark blue, gray and buff, effervescence indicates magnesian limestone, but not dolomites	197	1208

	RECORD OF STRATA.	THICKNESS.	DEPTH.
57.	Gypsum and shale, gypsum gray and white in flakes, shale green, perhaps from above	15	1223
56.	Limestone, light blue, gray, highly seleniferous, with some flakes of gypsum	145	1368
55.	Limestone, cherty, arenaceous, grains of sand minutely rounded, much shale in rounded fragments, perhaps from above	22	1390
54.	Dolomite, buff, crystalline, granular, with much chert and some chalcedonic silica, three samples	55	1445
53.	Shales in large fragments, purplish yellow and green, non-calcareous, finely laminated, gritty	33	1478
52.	Dolomite, in yellow gray powder, cherty	260	1738
51.	Dolomites, yellow, buff and brown, mostly cherty and residue finely quartzose, five samples	155	1938
50.	Shale, green, very slightly calcareous	8	1946
49.	Dolomite, brown, arenaceous	30	1976
48.	Shale, dark green, hard, "fossiliferous," practically non-calcareous	10	1986
47.	Sandstone, fine white grains moderately well rounded	39	2025
46.	Shale, drillings consist of greenish powder of dolomite chert, fine quartz sand, green shale and pynte	7	2032
45.	Dolomite, arenaceous and cherty	30	2062
44.	Shale, drab, calcareous in part, finest powder containing grains of buff cherty dolomite	23	2085
43.	Dolomite, gray	5	2090
42.	Dolomite, same with minute rounded vesicles resembling matrix of oölite from which grains have been dissolved	5	2095
41.	Dolomite	5	2100
40.	Shale, as No. 44, exceedingly hard to drill	4	2140
39.	Dolomite, arenaceous, gray, two samples	8	2148
38.	Shale, drab, calcareous	6	2154
37.	Sandstone, white, fine, calciferous	10	2164

explanation is in accord with the fact that analyses and physical tests of many of these clays show that they have not passed through the process of leaching by which others have lost their percentage of fluxing impurities, lime, magnesia, iron oxide and alkalies. This is quite commonly true of the so-called fire clays of the coal measures. The main mass of the argillaceous material shows, however, a distinct shaly structure. This is probably the expression of cleavage developed parallel to bedding. The sedimentary lamination may be quite fine but is frequently the opposite. It is shown in perhaps average character in figure 44, a detail from the pit of the Newman Brothers Brick Co. near Hastie. It may be seen equally well in any of the large clay pits near Des Moines.

The argillaceous shale passes by insensible gradations into sandy shales and this again into well defined sandstone. This transition is excellently shown along the railway track at the foot of Capitol Hill. Sandy shales are common throughout the coal measures. They are frequently of considerable thickness and lateral extent, and they exhibit most intimate relations with the great body of the argillaceous shale. They are in marked contrast with the sandstones into which they grade, in that the latter occur over narrow limits usually in sharply defined bodies. The shale gives long gentle erosion slopes. The sandstone yields narrow tortuous ravines with steep sides. Within Polk county the silicia is usually disseminated throughout the shales. Sandstones are relatively rare. In the southeast portion of the area is the Ford sandstone. On the north of the river between Runnells and Adelphi thinner sandstone beds are encountered at several points, and borings on the upland north of Morgan Valley shows sandstone common in the region. At the foot of Capitol Hill is the sandstone shown in figure 45 which, passing over the anticline at the Center street dam is seen at Thompsons bend and again near the Sixth street bridge at the locality long known as the Devils Gap. Across the river a sandstone, probably of the

RECORD OF STRATA.	THICKNESS.	DEPTH.
9. Shale and dolomite, shale hard, dark bright green slaty Dolomite white, highly siliceous, with much greenish translucent amorphous silica. Two samples of the second; over one-half the weight of the sample is soluble in acid	20	2730
8. Sandstone, buff in color, in powder, glauconiferous. This rock is termed sandstone although composed chiefly of light colored partings of impure cryptocrystalline silica which effervesces freely in acid; fragments of crystalline quartz form but a small proportion of the drillings	20	2750
7. Sandstone, saccharoidal, dark, with purplish tinge, dark color owing to numerous grains of glauconite, purplish tinge to ferruginous stains on quartz sand; sand grains rough surfaced, imperfectly rounded, many fractured of crystalline silica	130	2880
6. Dolomite, dark gray-greenish tinge, macrocrystalline, glauconiferous, sparingly arenaceous	5	2885
5. Sandstone, greenish, grains microscopic	5	2890
4. Shale, dull gray, fine grains and exceedingly finely laminated	5	2895
3. Sandstone, glauconiferous, calciferous, grains imperfectly rounded, with hard dark green slaty shale	15	2910
2. Marl in buff flour, microscopically arenaceous, calciferous, glauconiferous	50	2960
1. Marl, pink, calciferous, arenaceous, one-third of drillings by weight insoluble in acid, to bottom of well	40	3000

SUMMARY.

NOS.	FORMATIONS.	THICKNESS.	DEPTH.	A. T.
78	Pleistocene	14	14	858
68–78	Des Moines	484	498	374
66–67	Mississippian	200	698	174
62–65	Kinderhook	160	858	14
61	Devonian	80	938	-66
54–60	Silurian (upper)	507	1,445	-573
53	Maquoketa	33	1,478	-606
48–52	Galena-Trenton	508	1,986	-1,114
47	Saint Peter	39	2,025	-1,153
39–46	Upper Oneota	124	2,149	-1,277
25–38	New Richmond	94	2,243	-1,371
24	Lower Oneota	175	2,418	-1,546
8–23	Saint Croix	332	2,750	-1,878
1–7	Basal sandstone	250	3,000	-2,128

BASE OF THE COAL MEASURES.

At Mitchellville, with an altitude of about 976 feet, a boring put down to a depth of 264 feet* passed through forty feet of material which probably belongs to the Saint Louis. This would make the altitude of the base of the Saint Louis about 760 feet at this point. In borings made upon the river bottom near Carbondale, the Saint Louis was reached at about 200 feet below the river, or at about 600 feet A. T. At Valley Junction the limestone is said to have been found at about the same level, while south of Millman one boring, if properly interpreted, would bring it still nearer the surface. In the Greenwood Park well the coal measures were found to extend to a depth of 498 feet, or to altitude 374. At Commerce, on the other hand, Saint Louis lies at least 550 feet below the surface, or about 300 feet A. T.

While a certain amount of doubt is attached to some of these borings, and it is impossible to verify them at this date, it is believed that the underlying limestone will be found to exhibit in this region the same irregular surface which it shows farther east in its area of outcrop. Indeed the differences shown by the borings are even greater than those known to occur elsewhere.

*Second Bien. Rept. State Mine Inspector, p. 115. Des Moines, 1885.

The Greenwood Park drillings were carefully collected and studied and the record is believed to be especially trustworthy, despite the fact that it shows certain exceptions to the stratigraphy of the region. The well shows no coal, though situated not far from mines now producing and very near to points at which coal has been mined. As will be seen later, however, this fact is not a matter of so much surprise, as barren holes are frequently put down in the midst of productive coal fields, particularly in the Iowa-Missouri region.

GENERAL CHARACTER OF THE COAL MEASURES.

The coal measures of Polk county belong to the stage which the survey has called the Des Moines formation. When first studied by Owen* and later by Worthen,† no attempt was made to divide the coal measures. White‡ considered them to be made up of three formations which he called Lower, Middle and Upper Coal Measures. The beds of the southwestern portion of Polk county were assigned to the middle division, while those underlying the remainder of the county were put in the lower division. Keyes§ has divided the series into two terrains, the Missourian and the Des Moines, and more recently has considered the two divisions to be independent series.‖ It is the Des Moines, or lower stage, which is represented in Polk county.

The beds which have been included under the name Des Moines formation form a complex of shales, sandstones and coals, with a few thin limestones intercalated. Their variety is quite well shown in the following general section of the Carboniferous strata found above the water level in the vicinity of Des Moines.

	FEET.	INCHES.
18. Variegated clay shales	13	
17. Blue limestone, nodular, impure, weathering brown, fossiliferous		8
16. Variegated shales	8	

*Owen: Geol. Surv. Mo., Iowa and Minn., p. 121. 1852.
†Worthen: Geol. Iowa, vol. I, p. 171. 1858.
‡White: Geol. Iowa, vol. I, p. 231. 1870.
§Keyes: Iowa Geol. Surv., vol. I, p 85. 1893.
‖Am. Jour. Sci. (4), vol. II, pp. 211-225. 1896.

		FEET.	INCHES.
15.	Bituminous shale, with concretionary calcareous masses below, fossil-bearing	3	
14.	Coal	2	
13.	Light yellow and drab shale	7	
12.	Variegated clay shale	4	
11.	Limestone		8
10.	Shales, variegated, clayey	4	
9.	Limestone, nodular, earthy, passing in places into marl, highly fossiliferous		6
8.	Clay shale, light colored	5	
7.	Sandstone, soft, micaceous, becoming in places an arenaceous shale	20	
6.	Shale, clayey, gray, yellow and red in color	8	
5.	Sand rock, grayish, soft	4	
4.	Coal, impure, divided in places into three thin seams, varying considerably in thickness	2	
3.	Shale, light gray, fissile	5	
2.	Shale, light to dark gray, micaceous below, bituminous above	6	
1.	Shale, white, siliceous	10	

Nos. 1 to 7 inclusive are shown at the pit of the Iowa Pipe & Tile Co.; Nos. 7 to 12 are exposed at the south end of Capitol Hill; Nos. 12 to 18 are shown in street cuttings and clay pits in the northwestern portion of Des Moines.

As will be seen, the shales are predominant, and exhibit many facies. Details of their lithological characters are shown in the sections later described and are noted in the descriptions of the brick pits. There are three fairly well defined types. The more common perhaps is the argillaceous phase. This shale varies widely in color, showing shades of red, blue, green and yellow. It is in the main a clay, and may or may not show the shaly partings often considered the distinguishing feature of shales. The absence of these partings is often a matter of weathering, as shown by their greater prominence at fresh exposures.

At certain points argillaceous shale grades directly into the clay found under coal seams and commonly known as fire clay. The suggestion, of course, is that the change here

was due to weathering, and that loss of structure was one of the steps in the process of change from shale to soil. If we are to believe that each coal seam rested upon a soil, this might be the correct explanation, and probably is in some cases. Many coal seams, however, do not rest upon soils or anything of the nature of soils, and it seems not unlikely that the closeness of the relations between the coal and its

FIG. 44. Clay shales in the pit of Newman Bros. Brick Co., near Hastie.

underlying fire clay has been too much insisted upon. The presence of considerable bodies of loess showing no lamination whatever, in such situations and under such conditions that its origin by aqueous deposition can not be doubted, may be taken as evidence that lamination is not a necessary characteristic of sedimentary beds, and it may reasonably be maintained that much of the non-laminated material forming the so-called fire clays of the coal measures was originally deposited in its present condition. This

explanation is in accord with the fact that analyses and physical tests of many of these clays show that they have not passed through the process of leaching by which others have lost their percentage of fluxing impurities, lime, magnesia, iron oxide and alkalies. This is quite commonly true of the so-called fire clays of the coal measures. The main mass of the argillaceous material shows, however, a distinct shaly structure. This is probably the expression of cleavage developed parallel to bedding. The sedimentary lamination may be quite fine but is frequently the opposite. It is shown in perhaps average character in figure 44, a detail from the pit of the Newman Brothers Brick Co. near Hastie. It may be seen equally well in any of the large clay pits near Des Moines.

The argillaceous shale passes by insensible gradations into sandy shales and this again into well defined sandstone. This transition is excellently shown along the railway track at the foot of Capitol Hill. Sandy shales are common throughout the coal measures. They are frequently of considerable thickness and lateral extent, and they exhibit most intimate relations with the great body of the argillaceous shale. They are in marked contrast with the sandstones into which they grade, in that the latter occur over narrow limits usually in sharply defined bodies. The shale gives long gentle erosion slopes. The sandstone yields narrow tortuous ravines with steep sides. Within Polk county the silicia is usually disseminated throughout the shales. Sandstones are relatively rare. In the southeast portion of the area is the Ford sandstone. On the north of the river between Runnells and Adelphi thinner sandstone beds are encountered at several points, and borings on the upland north of Morgan Valley shows sandstone common in the region. At the foot of Capitol Hill is the sandstone shown in figure 45 which, passing over the anticline at the Center street dam is seen at Thompsons bend and again near the Sixth street bridge at the locality long known as the Devils Gap. Across the river a sandstone, probably of the

same horizon, is frequently struck in wells at Highland Park. East of this point, and across the old valley already described, sandstone is frequently encountered near the surface in the ridge between the old river valley and that of Four Mile creek. A thin sandstone occurs immediately under the drift at the Saylorville mine, and heavy sandstone ledges outcrop along the south side of the Des Moines immediately below

FIG. 45. Sandstone at the foot of Capitol Hill.

the mouth of Beaver creek. South of the river thin sandstones occur near the old Eclipse mine and south of Commerce. Nowhere, however, are there any massive sandstone deposits comparable to those found at Red Rock, in Marion county, and at many other points in the state. The sandstones present are essentially local in distribution, and while the Capitol Hill, Thompsons bend, Devils Gap and probably Beaver creek sandstones not improbably belong to the same horizon, their correlation is made upon other grounds than their lithological identity and proximity.

The third phase of shale is that exhibited in the bituminous facies. This is black, usually shows well developed cleavage

parallel to the bedding, frequently contains a considerable amount of coaly material, and passes by gradation through "black jack" to coal. It is closely connected genetically with coal and frequently occurs directly over coal seams. For this reason it is considered a hopeful sign by prospectors and is eagerly sought. It occurs, however, not rarely where no coal seam is present, or where the latter, though present, is not workable, so that it is far from being a reliable guide.

Bituminous shale usually contains a certain percentage of both lime and iron. In some instances these assume undue proportions and the result is the formation of clay-ironstone, a low carbonate iron ore known usually to the miners as "nigger heads." These clay-ironstone masses occur in the coal, along the horizon between the coal and the overlying shale or slate, and up in the latter. They frequently cause considerable trouble in mining, though at other times when the material is disposed in the form of a sheet rather than a lenticular mass they make an excellent roof.

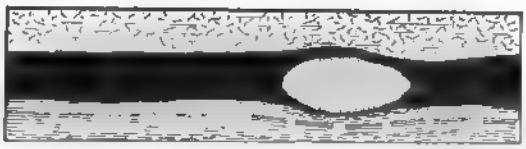


FIG. 46. Ironstone mass in coal bed of Bloomfield mine, Des Moines.

These clay-ironstones have been found in several of the mines and were quite well shown in the old Bloomfield mine on the south side.* As seen here they varied in size from horizontal dimensions of a few inches up to ten or twelve feet. In thickness some were as much as six feet. An analysis of similar material from a mine in Mahaska county showed the presence of about 88 per cent of limestone, with 8 per cent of organic matter and small percentages of iron oxides and sulphides. The rock is therefore essentially an impure limestone.

The bituminous shale also grades into that of the argillaceous type. It becomes less and less black and usually shows

*Keyes: Iowa Geol. Surv., vol. II, pp. 279-281. Des Moines, 1894.

a corresponding decrease in the perfection of the cleavage. This is well in accord with the fact that coal which has suffered much compression is finely laminated and splits easily. The bituminous shale often contains notable percentages of coal and has suffered corresponding diminution in bulk. Cleavage of the grade found here, which perhaps to some extent depends upon original lamination, is brought out by pressure and the changes due to it. The sandstones and sandy shales have suffered little compression, the clays and argillaceous shales more, the bituminous shales still more and the coal most of all. The cleavage increases in a corresponding order, the exceptions being certain clays probably not originally laminated, and coal where the chemical change has often been sogreat as to ob-scure the texture. The clay-ironstones have withstood the pressure, so where they occur in the coal the lamination planes of the latter bend round them as noted by Keyes.* In this they follow the law formulated by Van Hise,† that cleavage develops normal to the pressure, the latter being in this case normal to the surface of the ironstone mass which resisted compression. The phenomena is analogous to that of a bowlder of hard material in a squeezed conglomerate, and possibly the foliation sometimes observed in drift‡ may be explained by the same process.

In general throughout the shales the pressure is normal to the bedding and in the direction of gravity. While the results are slight, and in that particular correspond to the pressure, they seem to differ only in degree from the better developed phenomena known usually as cleavage. As defined by Van Hise, the phenomena of capacity to split into thin plates, so commonly seen in the bituminous and other shales of the coal measures and described in the previous reports of the Iowa Survey as fissility, falls rather under the definition of cleavage as seen above.

*Keyes: Iowa Geol. Surv., vol. II, p. 261. Des Moines, 1895.
†Prin. N. A. Pre-Camb. Geol., Sixteenth Ann. Rep. U. S. G. S., pt. I. p. 639. 1896.
‡Salisbury: Jour. Geol., vol. II, pp. 720, 721. Chicago, 1895.

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settles to a thickness of from one-tenth to one-sixteenth of that of the original mass of vegetal matter. This settling would under favorable circumstances show itself in the formation of a basin above, the basin in turn giving favorable conditions for coal formation. The formation of one coal seam thus opens the way for the formation of a second after such a time as would allow the accumulation of sufficient material to afford effective pressure. Where a coal seam is found under such conditions it should show in the upper bed the inequalities of the lower, and it is a suggestive fact that in the old Eureka mine when two seams were worked, this was found to be true. It must not, however, be considered as necessarily true that when two seams are found they fit together in this manner. In the Keb mine of the Whitebreast Fuel Co. at Ottumwa, there are two seams in which the thin parts of the upper overlie the thicker portions of the lower seam. In this case the two beds are only separated by a few feet of intervening strata, and it is possible that the amount of pressure due to the superincumbent material was not sufficient to be effective at the time of the formation of the second seam.

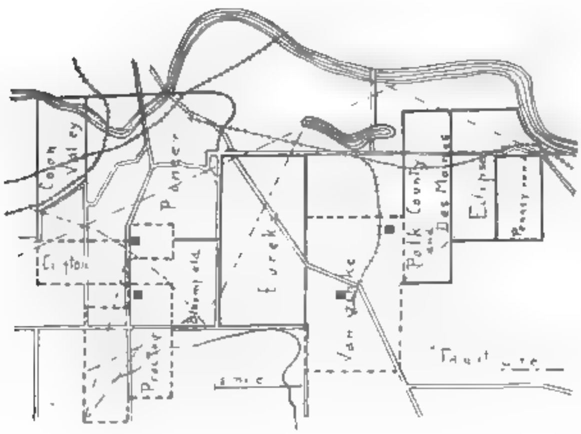


FIG. 47 Coal leases and "fault lines" in South Des Moines.

In the mines south of the river at Des Moines the rolling of the coal is a constant factor. The thinning of the beds is also common. The field is divided up into a number of smaller areas by a series of what are known as faults by the miners. With one exception these are probably not true faults in the

sense in which the term is used by a geologist. They do not, so far as known, mark lines of disturbance. The coal rises towards them on both sides and thins in the same direction, so that they seem rather to mark the original dividing lines between separate coal basins rather than lines of subsequent fracture. Since many of themines are now closed and in others the faults cannot now be examined this cannot be positively stated, and their distribution as shown on the sketch map may not be quite accurate though the map is made from the best obtainable information.

If, however, their origin be that surmised, the explanation of the fact that in no case was the coal found by drifting is easy. The limits of that particular basin had been reached in that direction. The presence, however, of a similar basin at about the same general level a short distance away is exactly what would be expected, so that the field as a whole shows a typical development of a coal horizon.

The exception among these fault lines is the one found east of the Coon Valley mines. From descriptions given by men who examined this, it seems to have been a true fault. If, however, this be the case, and there is some independent evidence favoring such an hypothesis, the throw is slight and the region affected is limited. An examination of the section from Capitol hill to Walnut creek indicates that within narrow limits the beds have suffered no disturbance.

The limestones of the coal measures are not prominent in the lower portion of the Des Moines terrain. In Polk county a few thin limestone bands alone outcrop. These rarely attain a thickness of so much as a foot. Their importance is, however, quite out of proportion to their thickness since they form such excellent stratigraphic horizons. In the vicinity of Des Moines there are at least three persistent limestone bands which afford the means of definitely correlating many of the exposures. Their use is seen in the sections which follow.

GENERAL CROSS-SECTIONS.

It is not possible at this time to present detailed sections across the entire county which would be of any value. Sections starting from Capitol Hill have been made north of the mouth of Beaver creek and west as far as Walnut creek. These sections were possible because of the presence of the thin limestones mentioned above. In the remainder of the county it is not felt that the data are of such value as to permit the exact form of statement given by a section.

SECTION FROM CAPITOL HILL TO THE MOUTH OF BEAVER CREEK.

The exposures along the Des Moines river from the mouth of the Raccoon to the mouth of Beaver are quite numerous and are typical for the region. At Capitol Hill the following excellent section may be made out.

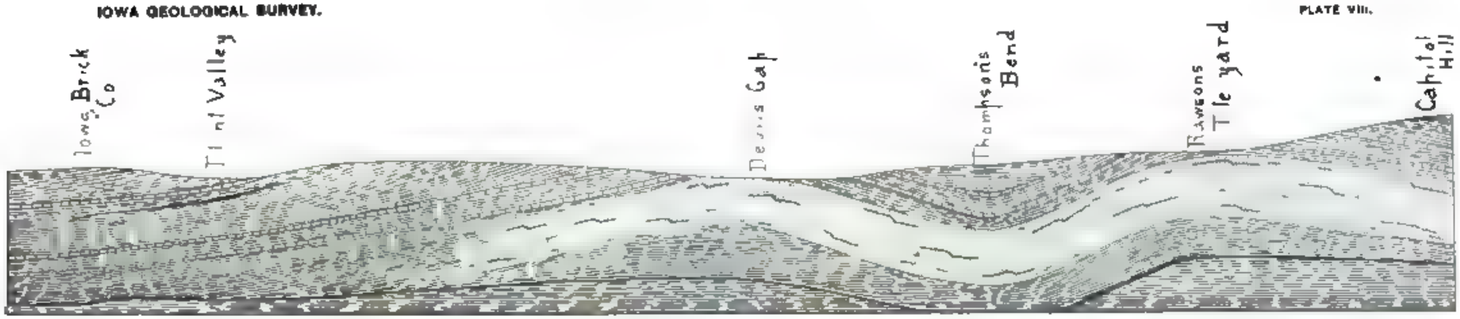
CAPITOL HILL SECTION.

		FEET.	INCHES.
11.	Variegated clay shales	25	
10.	Limestone		8
9.	Light gray to drab shale	4	
8.	Limestone		6
7.	Light gray shales	5	
6.	Sandstone, irregularly bedded, well exposed along the railway tracks at the foot of the hill	25	
5.	Shale, light gray	2	
4.	Coal	2	
3.	Shale, sandy	3	
2.	Coal		3
1.	Shales, light gray	2	

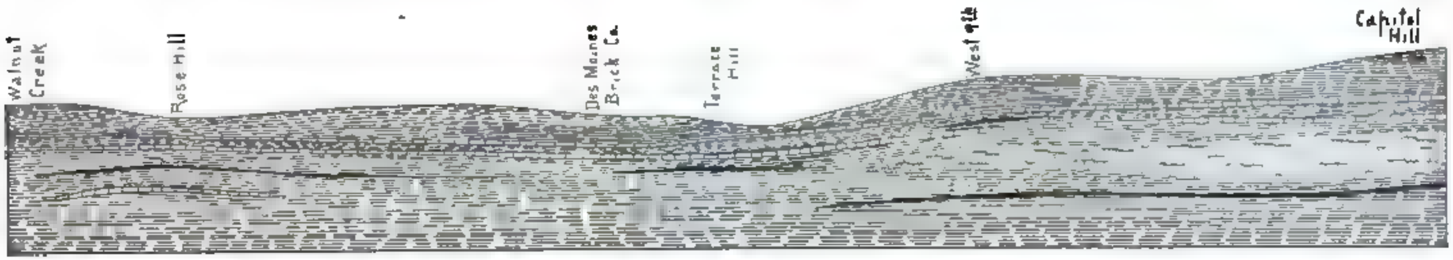
Numbers 1 and 5 are well shown at the east end of the exposure, but the rather unusually pronounced dip to the southwest carries them below the level of the railway track east of Ninth street.

TILE YARD SECTION.

At the east front of the hill, in the pit of the Iowa Pipe & Tile Co., the following excellent section is exposed.



GEOLOGICAL SECTION FROM CAPITOL HILL TO THE MOUTH OF BEAVER CREEK.



GEOLOGICAL SECTION FROM CAPITOL HILL TO WALNUT CREEK.

		FEET.
9.	Shale, argillaceous, yellow	20
8.	Shale, clayey, gray, yellow and red in color	8
7.	Sandrock, gray, soft	4
6.	Shale, black, in part clayey	1½
5	Sandrock, gray	4
4.	Coal, impure, shaley	1½
3.	Shale, light gray	5
2.	Shale, light gray to dark	6
1.	Shale, white, siliceous	10

Number 9 of this section may be correlated with number 6

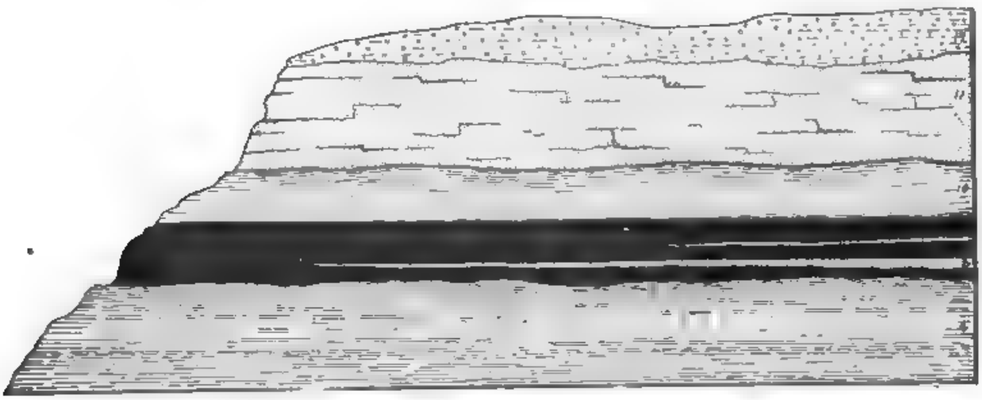


FIG. 48. Bluff on Des Moines river above milldam, at city of Des Moines. Shows coal seam separated by sand bands.

of the preceding. Above it in the hill numbers 8 and 10 of the Capitol Hill section are found at the correct level.

Across the river from the exposure just given is a better section, showing the coal bed divided into three parts. The dip is to the north and the three parts of the coal seam come together, the intervening sandstone partings wedging out as shown in the figure.

		FEET.	INCHES.
12	Drift	6	
11	Sandstone, soft, micaceous, buff in color, massive in places	10	
10.	Clay shales, light colored	5	
9.	Coal	2	6
8.	Sand, loose		6
7.	Coal	1	6

		FEET.	INCHES.
6.	Sandstone, massive, fine grained	2	
5.	Coal	1	
4	Clay shale, yellow and blue in color	10	
3.	Clay shale, dark drab in color	4	
2.	Shale, somewhat sandy	5	
1.	Shale, black, bituminous (exposed)	8	

The relations between these two exposures are seen in figure 49, representing a section across the river at the dam.

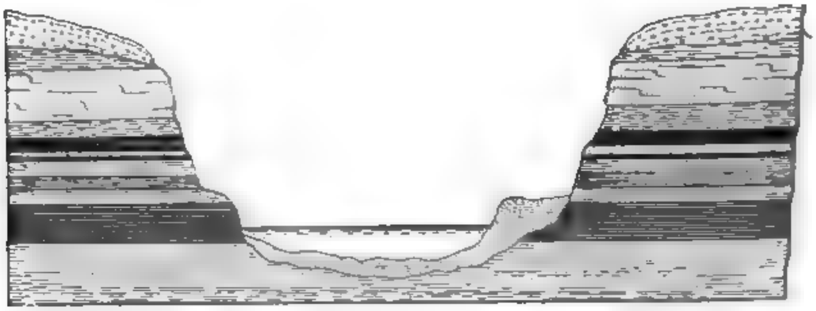


FIG 49. Gorge of Des Moines river at city of Des Moines.

The heavy dip north carries the coal down to the water level at Thompsons bend. It is here a good workable seam and has been opened up from time to time by means of drifts.

Towards the west the strata rise a little from Thompsons bend to Sixth avenue where the coal was formerly worked by drifting. In this vicinity at the point known as the Devils Gap is the following exposure.

DEVILS GAP SECTION.

		FEET.
4.	Sandstone, yellow, massive	15
3.	Shales, variegated	2½
2.	Shales, light, sandy	15
1.	Hidden to river, with talus of coal and sandstone	20

The sandstone seen here is probably number 9 of the Rawson section. In the clay pits of the Flint Brick Co. and at neignboring exposures the strata exposed are as follows.

		Feet.	Inches.
13	Light colored clay shales	10	
12.	Limestone		8
11.	Green and yellow clay shale	5	
10	Bituminous shale	2	
9.	Purple and variegated shale	4	
8.	Yellow and white sandy clay	4	
7.	Limestone		8
6	Light colored clays	6	
5	Limestone		10
4.	Massive variegated clays and shale	20	
3.	Sandstone	1	
2.	Coal	3	
1.	Shales, drab	5	

Numbers 5 to 6 correspond to Nos. 8 to 10 of the Capitol Hill section. The other numbers are readily correlated.

Opposite Flint valley corresponding beds are shown at the pit of the Iowa Brick Co. and were found in the shaft of the Eagle Coal Co. The record of the latter is given below.

EAGLE COAL SHAFT.

		Feet.	Inches.
27.	Drift	14	10
26.	Red sandstone		8
25.	Red shale	3	
24.	Blue shale	11	7
23	Red and variegated shale	2	4
22.	Gray shale	4	8
21.	Coal	1	4
20.	Sandy shale	2	4
19.	Brown rock, hard		8
18.	Shale, sandy, light colored, hard	6	
17.	Blue shale	3	8
16.	Dark shale	2	6
15.	Light, sandy shale	31	4
14.	Hard rock	2	8
13.	Light shale, with hard bands	2	
12.	Light shale	3	
11.	Variegated shale	2	3
10.	Hard rock		6
9.	Coal, traces	4	
8.	Black shale	11	6
7.	Coal		9
6.	Light shale	2	7
5.	Dark shale	3	
4	Black shale	14	5
3.	Cap rock	1	5
2.	Coal	4	7
1.	Fire clay	6	

Number 21 is to be correlated with number 2 of the preceding section. Beyond the Eagle mine are the two Keystone shafts and that of the West Riverside Coal Co., all of which reach the same coal horizon. Between the West Riverside mine and the mouth of Beaver creek the bluffs show the presence of both sandstone and shale, but neither here nor on the opposite side of the river are the exposures of such character as to warrant definite correlation. Along Beaver creek there are practically no exposures of the underlying rock as would be expected from the history of that stream. The narrow gorge of the Des Moines shows many exposures of shale and thin beds of sandstone with a few coal outcrops, but the strata have so little to characterize them they yield nothing to stratigraphic study.

SECTION FROM CAPITOL HILL TO WALNUT CREEK

The beds found at Capitol Hill may, by means of the limestones present, be readily correlated with those on the south side of the river. These are quite well exposed at the south end of the West Ninth street bridge, where the following beds may be seen beneath the drift.

		FEET.
8.	Shales, light gray	6
7.	Limestone	½
6	Brown sandy shales	5
5.	Dark drab shales	2
4.	Light shale	1½
3.	Limestone	1
2.	Light colored shales	10
1.	Shaly sandstones	6

The base of this section is the Chicago Great Western railway track, which is here forty feet above the river. The upper limestone, number 7, is fifty feet below the mouth of the Clifton mine on the hill. The Pioneer mine was located near this point, the "third" vein being found at a depth of 150 feet. On top of the hill, south of the section just described, is the Clifton shaft.

CLIFTON SHAFT RECORD.

		Feet.	Inches.
42.	Drift	11	
41.	Soft sandstone	2	
40.	Clay shale	9	
39.	Limestone		8
38.	Clay shale	8	
37.	Limestone		9
36.	Clay shale	5	
35.	Black shale	2	
34.	Coal		10
33.	Fire clay	2	
32.	Hard sandstone	3	
31.	Soft sandstone	3	
30.	Fire clay	3	
29.	Clay shale	12	
28.	Black shale	6	
27.	Coal	2	
26.	Fire clay	6	
25.	Sandstone	9	
24	Fire clay	6	
23.	Brown shale	2	
22.	Coal	1	11
21.	Fire clay	16	
20.	Hard sandstone	6	
19.	Fire clay	8	
18.	Clay shale	4	
17.	Coal	6	
16.	Fire clay	13	
15.	Shale, black	10	
14.	Limestone		10
13.	Shale, black	3	
12.	Coal, impure	3	
11.	Rock		3
10.	Coal	2	3
9.	Fire clay	8	
8.	Sandstone	2	
7.	Black shale	5	
6.	Sandstone	3	
5.	Black shale	5	
4.	Coal	1	8
3.	Fire clay	4	
2.	Black shale	10	
1.	Coal	5	6

The elevation of this shaft is about 890 A. T. The section cannot be exactly correlated with others in the vicinity.

though numbers 37 and 39 may represent the two limestones which, near the bridge, lie thirty feet lower. The coal of the Pioneer mine is believed to have belonged to the horizons now worked in the Clifton mine.

The beds seen at the Ninth street bridge are again exposed in the pit of the Capital City brick works a short distance southwest. The upper of the two limestones does not show in the pit but is seen in the following section.

CAPITOL CITY BRICK COMPANY.

		FEET.
5.	Shale, ash gray	6
4.	Limestone	1
3.	Shale, drab to yellowish	6
2.	Fire clay, purplish	4
1.	Shale, light gray	10

Opposite this pit is the section at the foot of Terrace hill, which is readily correlated with those already given.

TERRACE HILL SECTION.

		FEET.	INCHES.
9.	Shale, light colored; exposed	2	6
8.	Limestone, impure, nodular, weathering brown and containing fossils		8
7.	Shale, argillaceous, white and drab	5	
6.	Limestone, nodular, like number 8, but containing fewer fossils		8
5.	Shale, dark drab below, light colored above	4	
4.	Shale, bituminous, fissile, with coaly streaks	2	6
3.	Coal	3	
2.	Shale, light colored, somewhat sandy	6	
1.	Sandstone, somewhat shaly, concretionary in places, exposed above track level	6	

Still farther west in the pit of the Des Moines Brick Manufacturing Co. the same beds may be seen.

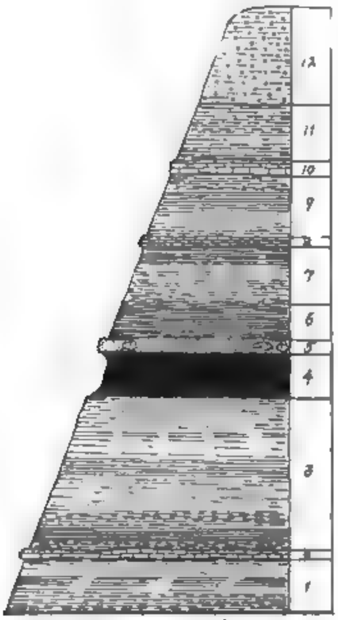
SECTION AT DES MOINES BRICK WORKS.

		FEET.	INCHES.
10.	Shale, variegated, with weathered band of limestone	7	
9.	Shale, dark gray	2	
8.	Shale, light gray	3	6
7.	Shale, impure, sandy	3	
6.	Limestone		7

		FEET.	INCHES.
5.	Shale, dark gray, clayey	4	6
4.	Limestone		6
3.	Shale, dark and light gray	16	
2.	Sandstone, shaly	2	
1.	Shale, hard, siliceous	8	

The coal seen at the Terrace Hill section appears again at the usual horizon on the south side of the river near the old Rose Hill mine.

RAILWAY CUTTING NEAR ROSE HILL MINE.



		FEET.
12.	Drift	10
11.	Clay shales, red and drab, variegated	6
10.	Limestone, earthy, nodular	½
9.	Shales, variegated	5
8.	Limestone, impure, nodular	½
7.	Clay, yellow and drab, variegated	4
6.	Clay shale, dark drab, somewhat bituminous	2
5.	Ironstone, black, nodular	1
4.	Coal, impure	3
3.	Clay shale, hard, drab, somewhat sandy in places	15
2.	Limestone, nodular	1
1.	Clay shale, blue (exposed to track level)	6

FIG. 60. Railroad cutting near Rose Hill mine. Four miles west of Des Moines.

Below the base of this section, at a depth of seventy feet, the Rose Hill Coal Co. formerly mined a seam two to four feet in thickness. Near the mouth of Walnut creek (Tp. 78 N., R. XXV W., Sec. 11, Ne. qr., Se. ¼) beds corresponding to the last exposure may be made out.

		FEET.
13.	Red clay	3
12.	White sandy clay	3
11.	Sandstone	8
10.	Clay shale	1½

		FEET.
9.	Limestone	½
8.	Dark drab clay shale	3
7.	Clay-ironstone	½
6.	Coal	2
5.	Fire clay	1
4.	Variegated clay shale	5
3.	Limestone	½
2.	Sandstone	8
1.	Clay, light colored	1

This section fails to show the upper of the two limestones exposed in the other sections. Its close resemblance, however, to the last preceding section leaves little doubt as to the correctness of the correlation of the outcrop.

Beyond Walnut creek the sections are not sufficiently numerous to warrant definite correlation of the outcrops.

DETAILED STRATIGRAPHY.

In discussing the stratigraphy of the coal measures of the county it will be convenient to consider individual districts separately. The divisions are of course quite arbitrary as the strata of each region are represented in the adjoining areas. Between the districts, however, it is not possible in all cases to make correlations with any degree of certainty. In some cases the same uncertainty obtains as to the correlations within the districts. The results obtained, however, are not thought to be valueless. They may be considered in each case as the expression of the greatest probabilities as shown by evidence now in hand. Later prospecting and further mining development will test them and make more definite stratigraphic correlation possible. Until the details are much better known, and this knowledge can only come as the results of work with the drill, general conclusions only are possible, and the correlations here made must be considered as working hypotheses only to be constantly checked and amended.

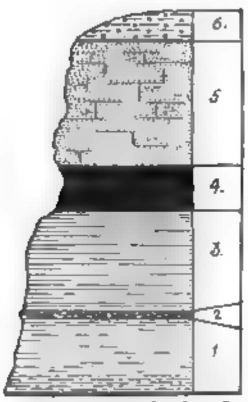
The term coal horizon is used here in the sense proposed by Keyes.* It does not mean a coal bed, but rather a strati-

*Jour. Geol., vol. II, pp. 178-186. Chicago, 1894. Iowa Geol. Surv., II, 168. Des Moines, 1894.

graphic horizon along which coal may be generally expected to occur. Coal is not found at all points along a coal horizon; nor is it found in equal thickness. The horizon does not maintain a constant level, entirely aside from any folding, or recent deformation. The coal may vary greatly as to thickness and position, and yet the general horizon is a marked stratigraphic feature, and is often constant for a considerable area, as will be seen in the following pages.

RUNNELLS-CARBONDALE DISTRICT.

The exposures along the Des Moines and its side ravines, taken together with the results of mining and prospecting, give quite full data throughout the district. About a mile east of Runnells a cutting along the Wabash railroad shows a coal seam as indicated below.



		FEET.
6.	Drift	4
5.	Sandstone, buff, heavily bedded	15
4.	Coal impure	4
3.	Clay, drab	10
2.	Shale, bituminous	1
1.	Shale, light colored, exposed	8

FIG. 51. Railroad cutting near east county line, below Runnells.

At Runnells the same coal seam outcrops and has been worked by slopes along the face of the bluff. More recently new mines have been opened back from the river, the coal being reached at a depth of forty feet. The coal has an average thickness of about three and a half to four feet. The related strata are better exposed across the river at Ford, where the bed has also been opened up by drifts. The Howell Coal Co. in working here found that the seam thinned down to six inches at one point, though elsewhere it was of normal

thickness. At a point near by a section measured by Dr. Keyes* showed the horizon occupied by highly bituminous shale. His section is as follows:

		FEET.
9.	Drift and loess	10
8.	Light yellow sandstone, soft, heavily bedded above, thinly bedded below, with much clay	35
7.	Dark shale, highly bituminous in places, with hard concretionary layers	2
6.	Fire clay with sigillarid roots	½
5.	Drab shales, somewhat sandy above	12
4.	White clay	3
3.	Soft sandstone, buff, heavily bedded	4
2.	White clay	4
1.	Sandy and clayey shales, exposed to water level	25

The sandstone of this section, number 8, is well exposed along the river for some distance, and has been called *in the* survey reports the Ford sandstone. It is not so well marked north of the river, though the corresponding horizon shows sandy shales with interbedded sandstone layers. Near Avon, where the Chicago, Rock Island & Pacific railway cuts off the nose of the bluffs north of North river, sandy shales, presumably of the same horizon, are exposed above the railway track. Below the sandstone the following section is shown by mining operations.

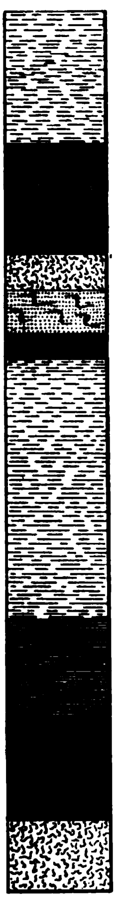
		FEET.
5.	Clay shales	5
4.	Coal, soft	1
3.	Sandstone, hard	1
2.	Shale, black	1
1.	Coal	3

Near here a boring was put down and no coal was found within forty feet of the horizon now worked. The elevation of the coal is about 800 A. T. It maintains the same elevation for a quarter of a mile, being reached by numerous drifts, in one of which the following section was measured.

		FEET.	INCHES.
6.	Shale, clayey, drab	2	
5.	Coal	1	8
4.	Clay	1	6
3.	Coal	1	3
2.	Fire clay	2	6
1.	Sandstone, in beds 3 to 8 inches thick	2	6

*Keyes: Iowa Geol. Surv., I, 97. Des Moines, 1893.

The coal is about on a level with the railway track. Toward the north the coal and sandstone rise till the latter is exposed to a thickness of ten feet, and underlying shales are seen. The dip on the north side of the anticline is slightly to the north, but mainly to the west, and is so pronounced as to carry the coal down to the old level, within 400 feet, where it has again been opened by drifting. The loess covers everything more or less, so that the relations are not well shown, but the sections in the drift mines and the pronounced dip to the west make them evident. Still farther north the coal maintains its usual level, as is shown by a series of abandoned drift mines. At the Manbeck mine, still farther north, the division in the coal seam becomes more pronounced. The general section at the mine is as follows.



		FEET.	INCHES.
12.	Shale, light colored above, bituminous below	6	
11.	Coal	1	3
10.	Clay, drab, carbonaceous, "clod"	1	
9.	Coal	3	
8.	Fire clay, light colored	1	5
7.	Sandstone, massive, yellow	2	
6.	Coal	1	2
5.	Fire clay and gray shale, "soapstone"	12	
4.	Shale, bituminous, hard and compact	3	
3.	Ironstone, irregular, nodular	1	8
2	Coal	3	4
1.	Fire clay	3	

FIG. 52. Part of shaft cf Manbeck mine. North of Avon.

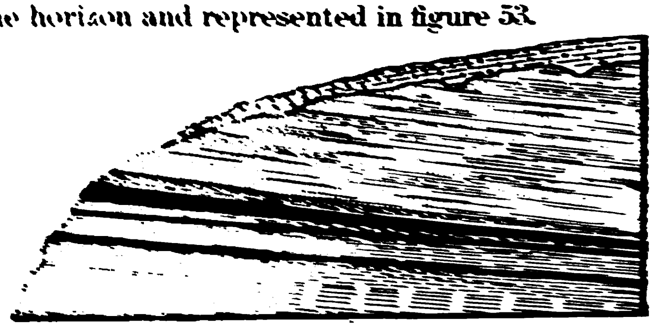
Numbers 9 and 11 seem to represent the Ford coal horizon. Number 6 not improbably also belongs with them.

Just north of the mine the railway makes a cut along the face of the hill. Here Keyes has measured the following section.

		FEET.	INCHES.
10.	Drift	6	
9.	Drab and brown clay, white in places, sandy above	6	
8.	Coal		8
7.	Sandstone, thin bedded	4	
6.	Clay, white, sandy	3	
5.	Sandstone, heavy bedded	5	
4.	Sandy shale	1	6
3.	Coal	1	4
2.	Drab clay, exposed	1	2
1.	Unexposed to water	25	

Number 3 of this may best be taken as representing number 11 of the preceding section.

Across the river from the Manbeck mine, at the location of the Newman Brothers brick plant, is a seam of coal marking the same horizon and represented in figure 53.



[illegible]

		FEET.	INCHES.
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	

The coal of this horizon was formerly worked by the Woodlawn Coal Co., by means of a drift. A higher seam with a thickness of twenty-eight inches is known to outcrop about thirty-five feet above its level. The mine of the Iowa Coal & Mining Co., located at the same place, shows a lower seam three to three and a half feet thick, lying about thirty-five feet below the Ford coal horizon. Still lower by an interval of twenty-five feet, a seam three feet eight inches thick occurs, and fifty-four feet below this a fifth horizon is marked by three inches of coal. At Hastie coal which would seem to represent this lower horizon four feet thick was formerly worked at a depth of 100 feet. The coal worked in the Carbondale mine seems to belong to the same horizon. A boring just put down near their new mine, number 2, showed the following strata.

		FEET.	INCHES.
21.	Soil	2	
20.	Marly clay	17	
19.	Sand and clay	3	
18.	Gray shale	39	5
17.	Sand rock and shale	3	9
16.	Limestone, white, brittle	1	10
15	Shale, light blue	1	6
14.	Shale, sandy	8	4
13.	Shale, light blue	1	4
12.	Sandstone	1	6
11.	Shale, gray	2	
10.	Sandstone	3	4
9.	Sandy shale	12	9
8.	Gray shale	5	5
7.	Coal and blackjack	1	2
6.	Fire clay	1	8
5.	Gray shale	1	1
4.	Rock, hard, gray		7
3.	Rock, hard, blue	3	8
2.	Shale, black	3	
1.	Coal	4	4

This record was proved when the shaft was sunk. In section 10 (Tp. 78 N., R. XXIII, W.) a boring showed a slight difference. The record is as follows.

		Feet.	Inches.
34.	Soil	4	
33.	Yellow clay	15	
32.	Sand and clay	23	
31.	Blue clay	4	
30.	Gray soapstone	5	
29.	Blue clay	39	
28.	Black shale	3	
27.	Sandstone	2	
26.	Gray shale	6	
25.	Black slate	1	6
24.	Coal		8
23.	Fire clay	3	
22	Gray soapstone	4	
21.	Black shale	22	
20.	Coal	4	
19.	Pyrites		6
18.	Fire clay	3	
17.	Soft sandstone	1	
16.	Shale, clayey, white	6	
15	Sandstone	1	6
14.	Shale, clayey, brown	2	6
13.	Shale, black	10	6
12.	Sandstone	1	6
11.	Shale, clayey, white	1	
10.	Sandstone, gray, hard	3	7
9.	Pyrites		1
8.	Shale, gray	19	
7.	Sandstone, hard*	6	
6	Shale, gray	13	
5.	Rock, hard	1	6
4.	Shale, black	2	6
3.	Pyrites		3
2.	Shale, black	2	
1.	Coal	4	9½

Number 1 in each record seems to represent the same horizon. Number 7 of the first apparently is not represented in the second, while numbers 20 and 24 of the latter are not represented at the shaft. In the same section with the last given boring a seam twenty-eight to thirty-two inches thick crops out along a ravine. It not improbably represents number 24 of the boring. A boring made in section 9 Nw. of Ne. shows five feet of coal at sixty feet. As this boring was started

on the upland, the coal probably belongs to the horizon of number 24.

The thin seam outcropping along the ravine would seem to belong with the Ford coal horizon. The thicker vein found below number 20 of the last record, not unlikely represents the lower coal mined at the Manbeck mine, or the Manbeck horizon. This horizon does not seem to be generally represented and is apparently of local importance only.

Not far from this point the Crescent Coal Co. of What Cheer, Iowa, did some prospecting in 1893. One of the bore holes was carried down to the Saint Louis, and through the courtesy of Mr. S. W. White, vice-president and general manager of the company, the record is given below. It is of interest in that it was put down by experienced men with a diamond drill, and hence is particularly reliable. The coal seams found agree well in position with those known in the surrounding mines, number 17 probably representing the Hastie horizon. The nearness of the Saint Louis to the surface and the absence of lower coal seams is disappointing. The presence of black slate, number 11, twenty feet below the coal worked, may be considered as hopeful.

		FEET.	INCHES.
31.	Surface material	10	
30.	Sand and gravel	26	
29.	Blue clay	5	
28.	Slate	12	8
27	Coal	1	4
26.	Fire clay	3	
25.	Slate	3	
23.	Fire clay	4	
22.	Sandstone	22	
20.	Fire clay, mixed with coal	1	
19.	Sandy fire clay	4	
18	Soapstone	4	
17.	Coal and fire clay	1	
16.	Fire clay	2	
15.	Slate	2	6
14.	Sandstone	8	6
13.	Slate	3	
12.	Sandstone	2	

		Feet.	Inches.
11.	Black slate	2	
10.	Fire clay, with soft sandstone	6	
9.	Sandstone	16	
8.	Blue hard rock	4	6
7.	Sandstone	6	6
6.	Slate	6	6
5.	Blue rock	1	3
4.	Soft slate	5	3
3.	Hard blue rock	1	
2.	Soft slate	17	
1.	Limestone	3	6

The horizon found here, number 17, with that worked in the Carbondale mine, is probably the one worked in the Christy and Gibson mines on Four Mile creek. Near the Gibson number 2, a bore hole showed the following strata.

		Feet.
13.	Soil	2
12.	Red sand	12
11.	Blue clay	32
10.	Soft clay and sand	10
9.	Shale, black	32
8.	Coal	$3\frac{5}{8}$
7.	Fire clay	4
6.	Sandstone, soft	5
5.	Shale, black	15
4.	Cap rock	1
3.	Coal	$4\frac{1}{4}$
2.	Fire clay	$2\frac{1}{4}$
1.	Sandstone	7

The upper coal here, number 8, is not shown in several other borings and does not seem to be particularly persistent. In general position it corresponds to the first seam below that now worked by the Iowa Coal & Mining Co., but nothing more than this can be safely asserted. The lower seam, number 3, has been located over a considerable territory by the Gibson and Christy mining companies. But little doubt of its equivalence with the seam mined at Carbondale and formerly mined at Hastie, need be entertained. Since it was first mined at Hastie it may conveniently be referred to as the Hastie horizon. The Runnells, Ford, Avon and Woodlawn drifts took coal from the Ford horizon. The Manbeck horizon is probably represented over the Carbondale lands and possibly includes the Morgan Valley coal. The coal lying

thirty feet below that now worked at Morgan Valley can not be correlated, unless it be with the seam lying twenty-five to thirty feet above the Hastie horizon at the Gibson mine. This correlation is, however, doubtful.

In general the Ford and Hastie horizons are workable throughout the regions. At the Manbeck mine the Ford coal is not now worked because of the clay slips present, and for the same reason the Woodlawn company found it an expensive vein to work. The Hastie horizon seems to show less coal to the southeast, but is fairly reliable throughout most of the district.

EAST DES MOINES DISTRICT.

Mines were early established along the south and east fronts of Capitol Hill and the region has been very thoroughly prospected. The record of the strata at the Giant mine is typical for the district and has been recently verified by the sinking of the new Eureka shaft, where the first vein, 4½ feet thick, was found at 54 feet; the second, 3½ feet, at 71 feet; and the third, 4 to 5½, at 107 feet.

GIANT SHAFT RECORD.

		FEET.	INCHES.
11.	Drift	40	
10.	Shale, black and bituminous below, light colored above	16	
9.	Coal	4	
8.	Fire clay	2	
7.	Shale, light colored	12	
6.	Shale, bituminous	5	6
5.	Coal	4	6
4.	Fire clay	4	
3.	Shale, light colored above, bituminous below	30	
2.	Coal	6	
1.	Fire clay	1	

FIG. 51. Shaft of Giant No. 1. East Des Moines.

The three veins found here were worked by several mines. The coal of the lower vein was found to thicken and dip to the east. In mining in that direction the entries were driven into a region where the thin roof broke through and flooded the works.

The Giant shaft was sunk on the west side of the old Des Moines valley previously noted. Along its eastern side a series of mines, the Maple Grove, Union, and Western, have more recently been opened. These are on higher ground, so that it seems most probable that they do not mine the "third" vein, if indeed they get down to the "second" vein. Any correlation, however, across this valley is quite open to question. In a general way the Gibson number 1, which correlates well with the mines of the Carbondale-Runnells district may stand as a connecting link between the two districts. In this case the third vein at the Giant shaft would probably represent the Hastie horizon.

At the south foot of Capitol Hill the old Watson mine formerly took coal from a depth of forty feet below the railway track. If this Watson coal represents the first vein of the Giant shaft, as will be seen to be quite probable, and if, furthermore, the coal at the foot of Capitol Hill be the same as that now exposed at a corresponding level near the old Pennsylvania shaft on the south side, then the first vein on the east side would represent the horizon of the second of South Des Moines. The three veins of East Des Moines are believed to be represented in the three horizons mined in North Des Moines.

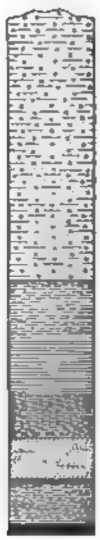
BERWICK DISTRICT.

In the vicinity of Berwick there are no mines, and but little prospecting has been done. A well put down for Mr. H. H. Taylor was carried down to a depth of 307 feet. The well started in the valley of Four Mile creek, perhaps ten feet above the railway, which would give an altitude of about 860 feet. The drift was about ninety to 100 feet thick and a three-foot vein of coal was struck at about 200 feet. In a second

well put down upon Mr. Taylor's land a thickness of seventy-two feet of drift was penetrated, below which were 100 feet of alternating sandstone and shales. In the Clendenin well near Berwick (Tp. 79 N., R. XXIIIW., Sec. 17, Nw. qr., Sw. ¼), situated well up on the upland, with an altitude of about 900 feet, coal four feet thick was encountered at 270 feet. The coal struck in these two mines would seem to lie lower than that worked upon the west side of Four Mile Ridge in the Union and Western mines. It not improbably represents one of the horizons worked in East Des Moines, but it is impossible at present to say which one.

ALTOONA-MITCHELLVILLE DISTRICT.

A mine was formerly operated at Altoona, being located just west of the station on the Chicago, Rock Island & Pacific railway. A section as shown by the shaft is figured below.



		Feet.
7.	Drift and Carboniferous clay	110
6.	Shale	60
5.	Sandstone	15
4.	Coal	1¼
3.	Shale	15
2.	Coal	4
1.	Fire clay	1

FIG. 55. Shaft of mine at Altoona.

The coal bed showed the usual undulations and had a general dip to the south. Both east and west of the shaft the coal became thinner, but it thickened in the direction of the dip. The mine was closed because of the water which came

into it. Near Mitchellville, and just outside the county, coal was formerly mined at the Cook shaft at a depth of ninety feet. The section shown by the shaft was as follows:

		FEET.
8.	Drift	27
7.	Black shale	3
6.	Coal	1
5.	Shale, gray and black	40
4.	Coal	½
3.	Shale, black and gray	15
2.	Coal	4— 5
1.	Fire clay	--

Three miles north of Mitchellville a test hole showed the following strata.*

		FEET.	INCHES.
17.	Drift	64	
16.	Yellow sandstone	4	
15.	Blue shale	11	
14	Black shale	2	
13.	Limestone		6
12.	Coal, impure		2
11.	Gray clay shale	8	
10.	Black shale	66	
9	Blue clay shale	21	
8.	Sandstone with pyrites	3	
7.	Gray clay shales	5	
6.	Sandy shales	4	
5.	Gray shales	12	
4	Sandstone with pyrites	16	3
3.	Gray clay shales	6	4
2.	Calcareous laminated rock	23	6
1.	Limestone with marly partings	16	

Numbers 1 and 2 of this section may be referred to the Saint Louis. It is quite impossible to correlate the strata at Altoona and Mitchellville with those occurring elsewhere in the county. On all sides between those points and the nearest productive mines is unprospected territory.

SAYLORVILLE DISTRICT.

On the north side of the old valley previously mentioned, coal has been encountered at a few points. The only mine at

* Second Bien. Rept. State Mine Inspector, p. 115. Des Moines, 1885.

present being operated is that of the Des Moines Coal Co. This shaft is 166 feet above the water level or 942 A. T. Three coal horizons were penetrated as is shown by the following record.

		FEET.
24.	Drift	49
23.	Soft sandstone	6
22.	Black shale	12
21.	Fire clay	12
20.	Rock	1
19.	Fire clay	3
18.	Black shale	5
17.	Fire clay	4
16.	Sandstone	3
15.	Fire clay and sandstone	22
14.	Hard rock	1
13.	Fire clay	6
12.	Shale, gray	4
11.	Coal	2½
10.	Fire clay	2
9.	Black slate	2
8.	Hard rock	1
7.	Black slate, with some coal	4
6.	Fire clay	2
5.	Hard rock	3
4.	Gray shale	31
3.	Coal	4½
2.	Fire clay	1½
1.	Sandstone	3

The lowest seam here seems to be best correlated with the first seam worked in the mines in East Des Moines. It has only been opened up by the one mine near Saylorville, though the upper seam was formerly worked out under the Poor Farm.

POLK CITY DISTRICT.

At Polk City the White Ash Fuel Co. operate a mine, taking coal from a depth of of 238 feet. The seam is split into two benches by an eight inch layer of black shale. The upper bench measures two and one-half feet, while the lower is one foot thick. The altitude of the mine is about that of the Saylorville shaft. There is no good record of the strata at this shaft, and no satisfactory correlations are now possible.

Farther north no coal is mined along the Des Moines within the limits of Polk county. A short distance beyond High Bridge (Tp. 89 N., R. XVI W., Sec. 14, Nw. qr.) there is a small country mine. Five seams of coal are claimed at this place. The first is shown in the bed of a stream near the mine and is fourteen inches thick. It was encountered in the shaft at a depth of sixteen feet. At forty feet a twenty inch vein was encountered, and at eighty-seven feet is the twenty-eight inch vein now worked. Borings are said to have shown a twenty-four inch bed, twenty-one feet still lower down, and four feet of coal at a depth of 171 feet. The property has not been developed and the extent of the beds is unknown.

COMMERCE DISTRICT.

The coal measures are exposed in the north river bank at at this place as is shown by the following section.

		FEET.
6.	Drift	25
5.	Clay shales, passing into sandy shales	20
4.	Buff sandstone, soft, thinly bedded	15
3.	Variegated clays	10
2.	Blue limestone, in three layers, separated by partings of marl	2½
1.	White shales (exposed to water level)	1

The three limestone bands are thought by Dr. Keyes to be the three which are seen in the hills at Des Moines. It is, however, impossible actually to trace the connection, though the correlation has every element of probability. The buff sandstone, number 4, is about on a level with the railway track. The mouth of the Merchant mine is not far from the same level, so that the coal now worked lies at about 750 A.T.

NORTH DES MOINES DISTRICT.

The thin seam of coal, number 2 of the Flint Valley section, which crops out along the river, was formerly worked at several points by drifting. More recently the Bloomfield, Flint, Lake Front, Oak Park, Eagle, Keystone 1 and 2, and the West Riverside mines have been sunk to a lower horizon

number 2 of the Eagle shaft section. These two horizons seem to be persistent throughout the district while certain intermediate ones are not so well marked. The upper coal is seen by the section from Capitol Hill to Beaver creek to be the same as that exposed at the dam and at the foot of the hill. The lower horizon would accordingly represent the third worked in East Des Moines.

The limits of the two horizons are not as yet worked out, and it is to be expected that considerable additional territory will be found to be underlain by workable coal..

SOUTH DES MOINES DISTRICT.

On the south side of the river at Des Moines, there are three horizons along which coal has quite generally been found. The first lies but little above the river, and has been at some points opened by drifting. The second is found about sixty to eighty feet below the bottom lands, and the third from 120 to 150 feet below the same datum. These three are not, however, the only horizons present, as may be seen by a study of the Clifton section already given. They do not always occupy the same level, as is evident if one compares the Clifton record with the following boring made near the old Bloomfield mine and starting fifty feet below the Clifton.

		FEET.	INCHES.
55.	Drift	15	
54.	Clay shale	10	
53	Shale, light colored	3	8
52.	Sand and clay shale	3	2
51.	Light gray clay shale	3	2
50.	Soft sandstone	2	2
49.	Light colored clay shale	3	10
48.	Sandstone		10
47.	Light clay shale	4	2
46.	Gray shale, hard	4	9
45.	Soft sandstone	6	5
44.	Clay shale	3	8
42.	Sandstone	9	10
41.	Clay shale, hard	6	
40.	Potters clay and sand	8	4
39.	Sandstone, hard	3	2

		FEET.	INCHES.
38.	Clay shale, light	6	3
37.	Clay shale, dark gray	2	2
36.	Coal	6	
35.	Dark clay with coal	1	6
34.	Fire clay	3	
33.	Sandstone	2	4
32.	Gray clay shale	2	4
31.	Coal		5
30.	Fire clay		3
29.	Sandstone	5	5
28.	Hard sandstone with pyrites		6
26.	Brown coal and shale	1	6
25.	Sandstone	4	
24.	Clay	5	
23.	Sandstone	1	
22.	Light clay	5	3
21.	Dark brown clay shale	1	4
20.	Light hard clay shale	2	6
19.	Soft clay	2	2
18.	Hard light clay shale	1	[illegible]
17.	Sandstone	4	[illegible]
16.	Very dark brown clay shale	[illegible]	
15.	Sandstone with pyrites	[illegible]	[illegible]
14.	Dark brown clay shales	[illegible]	[illegible]
13.	Clay	[illegible]	[illegible]
12.	Fire clay	[illegible]	[illegible]
	Sandstone	[illegible]	
10.	Dark brown clay shale	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

instead, number 13 stands as the representative of number 4 of the Clifton record, a vein not taken into account in current nomenclature. The lower vein has been shown by mining operations to be continuous in many of the south side mines and may well be taken as a datum plane. Upon this basis the three major veins fall into order fairly well when proper allowance is made for the rolling which is characteristic of all of them. There is some doubt, however, as to the correlation of these horizons with those worked elsewhere in the city. Opposite Capitol Hill, at the south end of the Chicago, Rock Island & Pacific railway, the following section is exposed.

		FEET.
13.	Light shale	6
12.	Limestone	½
11.	Light and dark shales	8
10.	Thin bedded sandstone	15
9.	Talus	6–10
8.	Coal	2½
7.	Fire clay	1½
6.	Variegated clay shales	3
5.	Light sandy clay shale	10
4.	Thin bedded sandstone	3
3.	Drab clay	1
2.	Clay-ironstone	1
1.	Bituminous sandy shale	2

The coal (number 8), sandstone (number 10) and limestone (number 12) all find their counterparts in the Capitol Hill section in sight from this exposure, and there accordingly seems little doubt that the coal here, which is the "upper" seam of the South Des Moines district, is number 4 of the Capitol Hill section. This would, as has been seen, make the second vein on the south side the first on the east side. It is probable, though not certain, that the third is the same on both sides of the river. The second as found on the east side may be unrepresented in South Des Moines, or may be equivalent to the coal already mentioned as occurring in the Clifton and Bloomfield mines, a short distance above the "third" coal. This correlation takes into account a thickening of the strata with a dip to the southwest.

LOWER COAL HORIZONS.

Whether or not coal of workable thickness exists below the horizons now worked is a matter of considerable economic importance. While the coal horizons now known are more than sufficient to supply present demand as well as any additional probable demand for some time to come, still when the mines near the city have worked out their territory, it will be necessary for them either to move farther out or to find new horizons lower down. The former entails considerable initial expense and the permanent charge for transportation into the city. Under such circumstances lower coal seams will become valuable. With almost no exception the actual location of workable coal throughout the Iowa coal field is the result of drilling. The horizon may in most cases be approximately located by stratigraphy, but the location of the workable coal is by drilling. What holds true in general is equally true of the case in hand. The general stratigraphy shows that the seams now worked are some distance above the base of the coal measures. Indeed they lie well toward the middle of the formation as it occurs in the county. In all the mining in the counties south and east of Polk it has been abundantly proven that the lower is the most productive portion of the formation. Indeed, the coal found in Keokuk, Mahaska and Wapello counties occurs so near the underlying Saint Louis limestone that its deposition has been conditioned by the irregularities in the surface of that formation. This portion of the coal measures is below that which has been prospected at Des Moines, and while it may not prove as productive in this area as it has elsewhere in the state there is no reason to doubt that it carries considerable coal. Aside from this general fact, however, there are certain others which seem to be confirmatory. A section along the Des Moines river from Harvey to Des Moines* shows the presence of several coal horizons which are stratigraphically beneath the beds exposed in Polk county. It is certainly to be expected that some of

*Keyes: Iowa Geol. Surv., I, 94. Des Moines, 1893.

these will be found to be productive in part at least. In a previous portion of this report it was suggested that the irregularities in the position of the coal beds of South Des Moines were to be explained by the presence under them of either an unconformity or a lower coal seam. There is no independent evidence of unconformity though local unconformities are known to occur throughout the coal measures. It would seem, accordingly, that the evidence here would at least fit in with that derived from other sources, and would indicate the presence of lower coal. The actual test of the matter must of course be by drilling, but, if one or even a half dozen drill-holes were to be considered conclusive, the question would now be settled. A very brief experience with such work will convince any one that a large number of carefully made drill-holes are necessary to obtain any reliable results. For example, it has already been shown that the drill at Greenwood park passed far below the horizons known to carry coal on all sides of the park and yet no coal was found. It is certainly fair to conclude that the absence of coal lower down in the same hole is no proof of its absence throughout the county. Two other deep holes have been put down in the vicinity. One was at the court house, the other near Saylorville. At this time it seems impossible to get any definite and accurate information with regard to these holes, but it is reported that they did not show deeper coal. Some time since the Crescent Coal Co. of What Cheer put down two diamond drill holes, starting on the bottom lands near Des Moines and carrying the borings down to the Saint Louis. These showed the probable presence of lower coal horizons, but not, at that point, of coal. The drill hole at Valley Junction is said not to have shown coal, while a deep hole at Commerce shows several horizons, at least one of which is workable.

On the whole it may be said that the prospect for finding lower coal is quite good but that there is no reason to suppose that the coal is any more evenly distributed than that now known, and its definite location calls for the same per-

sistent search that is made elsewhere when new coal fields are developed along the horizons already known. In all such work definite negative evidence is only obtained by carrying the holes down to the limestone, which may be anywhere from 200 to 400 feet below the river level.

FAUNA OF THE COAL MEASURES.

The beds exposed at Des Moines are quite frequently fossiliferous and considerable collections of characteristic forms may easily be made. Many of these forms were described and others were noted by Dr. C. R. Keyes during his residence in Des Moines. He has been so good as to summarize his published notes upon these fossils and to add to the list certain more recently noted forms. The species found belong to two distinct faunas, the one characterizing the thin limestone beds noted previously and the other occurring in the shales associated with the coal seams. In the following list, prepared by Dr. Keyes, the two faunas have been separated.

List of Carboniferous Fossils from Des Moines.

(BY C. R. KEYES.)

SPECIES IDENTIFIED FROM THE SHALES.

PROTOZOANS.

Fusulina cyclindrica Fisher.

CORALS.

Lophophyllum proliferum McChesney.

ECHINODERMS.

Archæocidaris edgarensis Worthen and Miller.
Eupachycrinus sp.?

BRYOZOANS.

Rhombopora lepidodendroides Meek
Synocladia biserialis Swallow

BRACHIOPODS.

Lingula umbonata Cox.
Orbitoidea nitida Phillips.
Productus nanus Meek and Worthen.
Productus cora D'Orbigny.
Productus muricatus Norwood and Pratten.
Chonetes lævis Keyes.
Chonetes flemingi Norwood and Pratten.
Chonetes mesoloba Norwood and Pratten.
Derbya crassa (Meek and Hayden).
Spirifer cameratus Morton.
Spirifer lineatus Martin.
Spirifer rockymontanus Marcou.
Athyris argentea Shepard.
Hustedia mormoni Marcou.
Rhynchonella uta Marcou.

LAMELLEBRANCHS.

Lima retifera Shumard.
Myalina swallovi McChesney.
Aviculopecten coxanus Meek and Worthen.
Aviculopecten neglectus (Geinitz).
Aviculopecten whitei Meek.
Avicula longa (Geinitz)
Nuculana bellistriata Stevens.
Nucula beyrichi Schauroth
Nucula parva McChesney.
Nucula ventricosa Hall
Macrodon obsoletus Meek.
Schizodus sp.?
Schizodus alpina (Hall).
Pleurophorus permianus Swallow
Pleurophorus subcuneatus Meek and Hayden.
Clinopistha radiata Hall
Solenomya soleniformis Cox
Astartella vera Hall.

GASTEROPODS.

Dentalium meekianum Geinitz.
Dentalium annulostriatum Meek and Worthen
Dentalium sublæve Hall.
Bellerophon percarinatus Conrad.
Bellerophon monfortianus Norwood and Pratten.
Bellerophon carbonarius Cox.
Pleurotomaria brazoensis Shumard
Pleurotomaria grayvillensis Norwood and Pratten.
Pleurotomaria carbonaria Norwood and Pratten

Pleurotomaria modesta Keyes.
Pleurotomaria sphærulata Conrad.
Pleurotomaria valvatiformis Meek and Worthen.
Murchisonia quadricarinata (Worthen).
Straparollus catilloides (Conrad).
Straparollus pernodosus Meek and Worthen.
Naticopsis nana (Meek and Worthen).
Trachydomia wheeleri (Swallow).
Loxonema scitula Meek and Worthen.
Loxonema multicosta Meek and Worthen
Soleniscus newberryi (Stevens).
Soleniscus humilis (Keyes).
Soleniscus gracilis Cox.
Soleniscus paludinæformis (Hall).
Sphærodoma medialis (Meek and Worthen).
Bulimorpha minuta (Stevens).
Bulimorpha? chrysalia (Meek and Worthen).
Orthonema conica Meek and Worthen.
Actæonina minuta Stevens.
Aclisina minuta (Stevens).
Aclisina robusta Stevens.
Streptacis whitfieldi Meek.
Anomphalus rotulus Meek and Worthen.

CEPHALOPODS.

Orthoceras rushensis McChesney.
Orthoceras lanskrensis Keyes.
Nautilis lasallensis Meek and Worthen.
Nautilis occidentalis Swallow.
Nautilis winslovi Meek and Worthen.
Goniatites nolenensis Cox.

CRUSTACEANS.

Cythere nebracensis Geinitz.
Phillipsia sp.?

VERTEBRATES.

Thrinacodus duplicatus? (Newberry and Worthen).
Deltodus intermedius St. John and Worthen.
Petrodus occidentalis Newberry and Worthen.

SPECIES FROM THE LIMESTONES AT DES MOINES.

CORALS.

Lophophyllum proliferum McChesney.
Cyathophyllum torquium Owen.

ECHINODERMS

Eupachycrinus cragini Meek and Worthen.

BRYOZOANS.

Rhombopora lepidodendroides Meek.
Synocladia biseralis Swallow.

BRACHIOPODS.

Chonetes flemingi Norwood and Pratten.
Chonetes mesoloba Norwood and Pratten.
Rhynchonella uta Marcou.
Hustedia mormoni Marcou.
Athyris argentea (Shepard).
Productus semireticulatus Martin.
Productus muricatus Norwood and Pratten.
Productus cora D'Orbigny.
Productus costata Sowerby.
Spirifer lineatus Martin.
Spiriter cameratus Martin.
Spirifer planoconvexus Shumard.
Spiriferina kentuckensis Shumard.
Derbya crassa (Meek and Hayden).

"These faunas are remarkable on account of both the number and variety of species represented and the great numerical representation of individuals The fossils are in an excellent state of preservation, enabling the minutest details of ornamentation to be clearly made out. Hence they are of more than local interest from several points of view.

There are two very distinct faunas represented. The one is a characteristic shore or brackish water phase, and is distinguished by great the predominance of gasteropods and lamellibranchs. It is found repeated at a number of horizons Its best development is in the bituminous shales over the coal beds. The other fauna is a more strictly marine one, in which the species are prevailingly bachiopodous and coralline. It occurs at three different horizons, in as many thin bands of limestone, none of which are over ten inches in thickness. All three horizons are present in the tops of the hills along the Des Moines. At the south end of Capitol and Terrace hills and in the bluffs of the Raccoon river the fossils are abundant.

In the general section already given the limestones from which the above fossils were collected are numbers 9, 11 and 17. The shales yielding most of the fossils were number 15, and the beds found immediately over the coal seams in the various mines

With regard to the fossils, certain general conclusions have been drawn.

(1) In those zoological groups having an optimum marine habitat, there are not only a small number of species present, but also an extreme paucity of individuals.

(2) The brachiopods, though well represented in both genera and species, were not proportionately as abundant as might be expected when it is remembered that this type of life had nearly reached its greatest expansion and culmination at the time these beds were deposited.

(3) The fauna was predominantly molluscan, more than three-fourths of the entire number of species being gastropods and lamellibranchs.

The Protozoa, Cœlenterata, Bryozoa and Echinodermata form a very inconspicuous proportion of this local fauna, only three or four specifically distinguishable members of each group being obtained Although the branchiopods are represented by fifteen species included in nine genera, they were, with three exceptions, of comparatively rare occurrence—*Productus muricatus*, *Chonetes mesoloba* and *Orbitoidea nitida* only being abundant. The brachiopods are also all depauperate, attesting conditions at the time that they lived extremely unfavorable to their full development and to the attainment of a normal size.

Molluscan forms, while certain of the black shales were being laid down, flourished luxuriantly, especially the gastropods, which in number of species composed more than one-third of the entire fauna. Not only did they exceed in species but they far outnumbered all others in individuals, and while as a rule they were small and some of them even minute, their vast numbers made up, in great part at least, for the conspicuity of large but fewer forms.

Although the majority of the forms of this group are small it is not a depauperation as among the brachiopods, as is shown by the average size of the individuals of each species being normal, and in some instances even considerably above. Some of the species are also of interest because of their recognition at this point for the first time within the limits of the state, and thus to a considerable extent their own geographical range has been increased Others of the species enumerated are now known to have a wide geographical distribution which is suggestive of a somewhat extended vertical range. Among recent mollusca and especially land forms a wide geographical distribution, as has been remarked by Binney, appears to be indicative of a high antiquity for the group The corroborative evidence is abundant; a notable instance is the living Zonites, four or more species of which are circumpolar in their distribution; and the genus—even a subgenus Conulus to which one of these living forms belong—ranges back to the Carboniferous, while the genus Pupa is represented in the Carboniferous by four species. Cephalopods are not abundant in the region under consideration, and are represented by only two genera and species, yet a Nautilus attained a diameter of twenty centimeters, and an Orthoceras was fifty centimeters in length, with a diameter at the larger extremity of five centimeters.

Of the lamellibranches the majority are small, though two of them are comparatively large, attaining a length of nearly ten centimeters, yet having an extremely thin and fragile shell. One of the specimens collected is of especial significance as exhibiting in all its details the internal features of the shell, the characteristic, well defined muscular scars and the edentulous hinge margin; in fact, it so closely resembles, in these characters—the general form and external appearance—a modern Anodonta, that it is difficult to see how it can be generically separate, and should further investigation prove that the specimen under consideration really belong to that genus, it would be of unusual interest in its bearing upon the distribution of fresh-water or non-marine mollusca during geologic times. The modern Unio and allied genera certainly have both a wide geographical and geological distribution, as is shown by the rich discoveries of Unionidea

in the Mesozoic strata of the west: and the genus Anodonta is, if the opinion of Hall is adhered to, represented in the Devonian by two species, but that these two forms really belong to Anodontais questionable. Dawson has described several allied forms from the Carboniferous of Nova Scotia; but their family position is as yet also unsettled. With these considerations in view, the evidence thus far obtained points to a high antiquity for this group of bivalves which now is so abundantly represented in all our streams and ponds. As will be noted, Crustaceans are represented by a species of Cythere; and a trilobites by a single pygidium."

PLEISTOCENE.

The Pleistocene series of Polk county includes the deposits of several separate stages. There are records of two and probably three ice sheets. Gravel horizons and a loess horizon indicate considerable changes in the freedom of drainage and by inference tell of changes in general altitude. There are unconformities and periods of considerable erosion. Buried soils tell of former climatic changes, and as has already been seen, the surface configuration reveals the fact that there have been in recent times marked changes in local geography. The series, for all its complexity, is not complete, and to obtain the full history of the region one must go outside the county for a portion of his facts.

PRE-KANSAN DRIFT.

In southern Iowa and northern Missouri there is at several points a distinct drift sheet lying below the Kansan drift, which forms the surface formation over much of the region. This pre-Kansan drift as exposed near Afton Junction, has been provisionally correlated by Chamberlain* with the Albertan† as proposed by Dawson. It has not yet been traced northward from the Union county outcrops, so that its equivalence with certain other exposures of drift presumed to represent the same horizon is at present open to some slight question. There are in Polk county two known exposures of a drift which is most probably to be referred to this horizon though the evidence is not quite so clear as might be desired.

* Editorial, Jour. Geol., IV, 872-876 Chicago, 1896.

† Jour. Geol., vol. II, pp 507-518. Chicago, 1895.

One of these exposures is at Thompsons Bend, in the city of Des Moines. Worthen,* in his notes on the Des Moines valley, mentions at this point, at the base of the drift deposits, a bed of ferruginous conglomerate three feet in thickness. The conglomerate is not now exposed, though pebbles, which apparently are derived from it, are abundant at the horizon mentioned. These pebbles include various greenstones and granites not found in any coal measure or Cretaceous conglomerates known in the state. They are of the same sort of material found in the drift and that is evidently their origin. They are badly weathered and iron-stained and in these particulars are easily differentiated from the pebbles of the overlying Wisconsin drift. They may safely be considered as pre-Wisconsin, but beyond that there is no certainty with regard to their age. In position and general appearance they strikingly resemble the older gravels occurring southeast of Hastie, yet to be described.

The exposure near Hastie (Tp. 76 N., R. XXIII W., Sec. 23) is one of the best along the river. The stream has been thrown against the eastern side of its wide valley and has cut back the bluff until a precipitous face 130 feet high fronts the bottom land, as shown in figure 40. The bluff has a historical interest since Owen† noted it and suggested that the marly earth capping the bluff was probably of the same age as the loess of Germany. Later Keyes and Call‡ studied the exposure and determined the presence of loess, till and stratified sands. The loess fossils mentioned below were collected and determined by them. The section shows the following beds.

		FEET.
5	Loess, usual texture and buff color, showing vertical jointing and perpendicular face, containing *Succinea avara* Say; *S. obliqua* Say; *Helicina occulta* Say; *Pupa muscorum* Linne; *Vallonia pulchella* Muller; *Zonites arboreus* Say; *Patula strigosa* Gould; *Mesodon thyroides* Say(?)	40

*Hall: Geol. Iowa, I, 171. 1858.
†Owen: Geol. Surv. Wis., Iowa, Minn., 121. 1852.
‡Proc. Iowa Acad. Sci., 1890-91, p. 30. Des Moines, 1893.

		FEET.
4.	Till, reddish brown above, becoming yellow below, and passing indefinitely into the formation below	20
3.	Till, blue, containing with the above, bits of chert, limestone, sandstone, coal, quartzite, badly weathered gray granites, diabase, fine-grained greenstone, mica schist, and dark green slate	30
2.	Stratified sand and conglomerate, imperfectly exposed	40
1.	Till, very dark blue, containing small pieces of fine-grained greenstone and rotten schist with bowlders of granite	1

All of these beds with the exception of number 1 are exposed in the bluff, though the lower portion of the latter is much obscured by talus. Number 1 is found in the bed of a small tributary and is seen to be covered by conglomerate similar to that seen in the bluff. The appearance of the lower drift is quite different from that above the conglomerate. It is darker in color, more compact, and contains fewer large bowlders so far as might be judged from the limited exposure examined.

The conglomerate is made up mainly of chert, but it also contains bits of quartzite, greenstone and of very badly weathered granite. It is quite firmly cemented by oxide of iron. It contains much the same sort of pebbles as are found in the accompanying drifts. Nothing distinctive in the character of the material could be made out between the different drifts or the conglomerate, though the lower drift and the conglomerate seemed to be more weathered. In the bluff there are apparently two ledges of conglomerate, each two to three feet thick, but the slipping which has taken place makes it impossible to be sure of this. Associated with the conglomerate are stratified sands of a bright orange color, bearing pebbles of chert and of northern rocks up to three-fourths of an inch in diameter.

The loess and the upper drift represent the formations common throughout the region and the drift is that called the Kansan. The sands and conglomerates are obviously water-laid. In appearance and position they resemble the gravels

found below the Aftonian peat beds. The drift below answers well to the sub-Aftonian drift. There is, however, no positive evidence here that the gravels are separated from the lower drift by any considerable interval, that is, that they are strictly interglacial. Neither is there, perhaps, conclusive proof that they are distinct from the Kansan drift. Until more is known of the drift of the region south the alternative theory, that the stratified beds simply represent water work during the advance or retreat of the Kansan ice, can not be altogether set aside. The beds seem to lie in the side valley of an older tributary of the main stream rather than in the main valley. The latter was apparently almost entirely cleared of such beds, if they were present, before the Kansan ice invaded the region. If this be indeed true, it would of course necessitate a certain amount of stream adjustment and a very considerable amount of erosion in the interval between the gravels and the Kansan. This is not in conflict with any known facts and is favored by not a few.

THE KANSAN DRIFT.

The principal drift sheet found in the county is that which in the previous reports of the survey has been referred to the Kansan period. It is in the main a stiff blue bowlder clay. It contains numerous pebbles, including especially greenstones of various types. It has a large amount of local material incorporated. The bowlders are predominately small as compared with those dotting the surface of the newer drift. In the area not covered by the Wisconsin, large surface bowlders are rare, and it does not seem that this is altogether the result of the obscurement due to the loess mantle. In the region south and west of Polk county there are considerable areas from which later erosion has removed the loess and within such areas the bowlders found on the surface and collected in the streams are neither so large nor so abundant as within similar areas covered by either of the later ice sheets which occur in Iowa. The difference in this regard is not so

striking when the Kansan and the Wisconsin areas of Polk county are contrasted as when corresponding regions covered by the Kansan and the Iowan in eastern Iowa are studied. It is, however, none the less a real difference and a valuable criterion for discrimination. The bowlders occurring in the Kansan are more frequently flattened and striated.

In the bluffs south of the Raccoon river and along the bluffs of the Des Moines below the city, the Kansan frequently outcrops and may be readily examined. While the bulk of this drift is a blue clay the portion most commonly seen is yellow, brownish or even red. Before it was buried under the loess it was exposed for a long period to surface action. The iron contents became highly oxidized, the soluble constituents were largely dissolved out, and at many places the finer material had been washed away, leaving a gravelly surface. It is this upper surface which is most frequently seen. It appears as a belt or zone along the sides of most of the streams of the loess-covered area. Above, the slope is covered by loess. Not far below, the alluvium obscures the drift. When any of the larger streams have been thrown to one side so as to cut away the overwash one may get a complete section, such as the one described near Hastie, except that the beds below the Kansan are not known to occur elsewhere. Good sections of the Kansan drift are rarely seen in this region. This is due to the fact that the topography of the country south of the Wisconsin drift area was almost wholly developed before the loess was deposited. The latter forms a mantle over this older surface, covering the Kansan almost entirely. Whenever there have been recent stream changes the Kansan is found. Its upper surface is readily recognized by the reddish brown color and the presence of many badly weathered bowlders. These characteristics are maintained not only when it is covered by the loess but when the latter becomes covered by the Wisconsin. On the west side of the Des Moines river at the Polk City bridge (Tp. 80 N., R. XXV W., Sec. 10), in passing up the hill one goes over the normal succession of coal measures,

Kansan drift, loess and Wisconsin drift. The same may be observed in crossing a small stream a mile north (Sec. 9, Ne. qr.), and indeed at a large number of points along the upper Des Moines valley. It is the normal succession. Lower till with the same characteristic outcrops has been noted by Beyer* still farther north, in Boone county.

Throughout the southern portion of Polk county this weathered horizon is constantly seen. Wherever the loess is cut through, the latter crosses the hill-tops, but is also found in the valleys as well. In road cuttings it is often possible to see the old Kansan horizon under the loess running down the slope to the bottom land. In such cases it is obvious that both the valley and the weathered horizon are earlier than loess. This is true for the major and most of the minor valleys of this portion of the county. Since the drainage is quite perfectly developed it must be clear that both lines of evidence point to the conclusion that there was a very considerable interval between the Kansan drift and the loess.

THE LOESS.

The loess of the Des Moines valley early attracted attention. Owen, as we have seen, correctly interpreted it. It was later studied in considerable detail by Call,† who made extensive collections of fossils from it. As usually exposed near the city it is the normal buff colored, fine-grained pebbleless material of porous texture, vertical jointing and calcareous reaction. It frequently contains fossils and lime concretions known as loesskindchen. It is quite irregular in thickness. At the fruit farm of Hon. J. G. Berryhill (Tp. 78 N., R. XXV W., Sec. 19) a well showed it to be seventy feet deep, on the west side of West Four Mile creek, while upon the opposite side of the valley the underlying Kansan outcrops near the top of the hill. In general, it is from ten to twenty feet thick over the southern portion of the county.

*Beyer: Iowa Geol. Surv., V, 203. 1895.

†Call: Amer. Nat. XV, 585-586, 783-784, 1881; XVI, 369-381, 542-549. 1882.

It may be seen particularly well developed in the brick pits on the south side of the river, or in the road cuttings along Clifton avenue, but is quite commonly exposed over the area indicated on the accompanying map. It is quite easily recognized by its texture, color, and freedom from pebbles. It is usually very fine-grained, but at points grades downward into a rather coarse sand. This may be seen at the south end of the Valley Junction bridge over the Raccoon river (Tp. 78 N., R. XXV W., Sec. 14). These coarse sands seem to be, in part at least, genetically related to the loess. They have not been found except in the Raccoon-Des Moines valley, or on the edge of uplands along it. At one point similar sands are found between two loess beds. This may be seen at the Dale-Goodwin brickyard (Tp. 78 N., R. XXIV W., Sec. 24, Ne. qr., Ne. ¼). The section shown in the hillside is as follows.

		FEET.
4	Soil, black	2+
3	Loess, buff to brown, with vertical jointing and normal appearance	3
2.	Sand, orange colored, cross-bedded, irregular in amount	1½
1	Loess, light gray, clayey, fossiliferous	8+

Under the lower loess is said to be a stronger brown clay. In the vicinity only the normal Kansan drift and loess is exposed. It is possible that the brown clay belongs to the coal measures. The presence of the bed of sand and the difference in character shown by the beds of loess suggest that they are here two separate loess sheets, the product of two widely separated periods of time. Two loess sheets have been noted at certain points in the older drift area.* In the present case, however, it does not seem necessary to resort to such an hypothesis. The sand bed is not present throughout the pit, wedging out entirely at the eastern end. It has not been observed elsewhere, and for the present at least there seems to be no necessity for considering the phenomena as of more than local significance.

* Salisbury: Ark. Geol. Surv., Ann. Rep. 1889, vol. II, pp. 224-248. 1891. Tilton: Iowa Geol. Surv., V, 318, 356. 1896.

The relations of the loess to the underlying drift have been already described. It remains to point out its relations to overlying drift. It has long been known that over the area covered by the Des Moines lobe no loess is found. South and west of the lobe, however, the loess appears. In 1882 Messrs. McGee and Call,* in a valuable and suggestive paper, brought out the facts that at Des Moines the loess passes under the upper drift, that now known as Wisconsin. Our knowledge of the drift formations was not then so well organized and the fact was interpreted as of local importance only and as due to a slight readvance of the ice now known as the Wisconsin, since what we now know as the Iowan drift was distinctly stated to occur south of the city. In the course of the present work the fact that the loess passes under the Wisconsin drift, as stated by McGee and Call, has been abundantly verified. The exposures mentioned by these authors are now obscured, but others equally good may be found wherever the drift on either the West Hill or in Highland Park is dug through. During the summer of 1896 the relations were particularly well shown at the top of the Sixth Avenue hill and in the cuts along Grand Avenue near Greenwood Park, and the street railway cutting on Hamilton street in Oak Park. The relations are unmistakable and may be verified at any time. The upper drift is quite distinctive and the buried loess is equally easy to recognize, since it is very frequently fossiliferous.

The relations found to obtain in the city are equally true of the loess to the north. In the wells near Saylor the normal section is as follows.

3. Yellow and blue pebbly clay.
2 Fine pebbleless clay with shells.
1. Blue clay with pebbles and streaks of gravel.

Loess fossils have been obtained from number 2 of this section at several points. On the farm of Mr. Tom Saylor thirty feet of pebbleless clay containing "periwinkle shells" is

* Am. Jour. Sci., (3), XXIV, 202-221. 1882.

reported below twenty-two feet of Wisconsin drift which forms the surface soil. Near the mouth of Beaver creek (Tp. 79 N., R. XXV W., Sec. 20, Nw. qr., Ne. ¼) a road side ravine shows the loess with its usual characteristics outcropping below the drift. The same phenomena may be seen at the localities west of Polk City, which have been already mentioned.

The relations observed in Polk county are not by any means local, but have quite as characteristic development in Dallas and Guthrie counties. It is believed that they are generally true of the southern border of the Des Moines lobe. It is not to be expected that the loess will be found to be preserved under the drift for any great distance back from its edge, though local bodies of buried loess may be found.

In view of this relationship it seems evident that the loess is not to be correlated with the Wisconsin drift. There is no good reason for separating it from the loess of eastern Iowa, with which it is continuous and which sustains such definite relations to the Iowan drift. The latter extends as far west as Marshall connty and is presumably the same as the drift of northwestern Iowa. The loess near Des Moines would seem to belong to the general loess sheet which was formed around the edge of the Iowan ice. It records a period of low levels when the drainage was clogged and the expanded waters of the rivers met across the divides. Under such conditions the deposition of coarser sands along the river valleys such as are found at Valley Junction would be natural.

The loess throughout the county is unusually fossiliferous. At many points in and near Des Moines considerable collections of the forms characteristic of the formation may readily be made. The fossils were thoroughly studied by Call during his residence in the city, and his results will be found in the papers already cited. Dr. C. R. Keyes has also made numerous collections and notes upon these forms, and has kindly prepared the following list.

REVISED LIST OF LOESS FOSSILS FROM DES MOINES.

Zonites arboreus Say.
Zonites minusculus Binney.
Zonites limatulus Ward.
Zonites fulvus Drap.
Patula alternata Say.
Patula strigosa Gould.
Patula striatella Anthony.
Helicodiscus lineatus Say.
Strobila labyrinthica Say.
Stenotrema monodon Rackett.
Mesodon clausus Say.
Mesodon multilineata Say.
Mesodon thyroides Say.
Vallonia pulchella Muller.
Pupa pentadon Say.
Pupa armifera Say.
Pupa muscorum L.
Pupa corticaria Say.
Pupa blandi Morse.
Vertigo simplex Gould.
Succinea obliqua Say.
Succinea avara Say.
Carychium exiguum Say.
Limnophysa desidiosa Say.
Limnophysa humilis Say.
Limnophysa caperata Say.
Helicina occulta Say.
Ferrussacia subcyclindrica Linn

WISCONSIN DRIFT.

The larger portion of Polk county was covered by the ice of the Des Moines lobe which ran down in a long tongue from the greater development of the Wisconsin ice in Minnesota. The area in this county which was so covered is shown on the accompanying map. The deposits of this ice sheet include not only the unstratified drift or till but a considerable amount of stratified gravel, more perhaps than has been so far observed in connection with any of the other drift sheets in Iowa.

The unstratified drift forms the great bulk of the Wisconsin formation. It is characterized usually by a buff to whitish

color, and by the presence of relatively unweathered material. There are some weathered bowlders, but these are, as compared with the Kansan, quite rare. The amount of local material found in the Wisconsin is notably less. There is a large amount of fine material in the matrix which is much like the loess. Ferrugination is quite rare. Lime is present in abundance, and the drift usually gives a reaction with acid up almost to the grass roots. Large bowlders seem more common upon its surface. So far it has not been found possible to base distinctions upon any difference in the kind of bowlders and pebbles found in the Wisconsin as contrasted with the Kansan. Apparently the material of both sheets was derived from much the same source. The most distinctive features of the Wisconsin till are its topography and relations to the loess, both of which have been discussed.

The Des Moines lobe seems to have been first recognized by Chamberlain,* who spoke of it as bordered by a half buried moraine. Previous to this White† had tentatively recognized Mineral Ridge in Story county as morainic, this being apparently the earliest recorded recognition of a moraine in the open country, away from mountain ranges. In 1890 Upham‡ traced the limits of the lobe but does not seem to have visited its southern terminus. In the portion visited by him it is quite generally bounded by a rather definite moraine. This has been called the Altamont moraine from a point in South Dakota, where it is particularly well developed. This moraine was quite fully described by him, and through association it has become common to think of the Des Moines lobe as terminated by the Altamont moraine. This is not, however, true for all parts of the border. The southern border of the Des Moines lobe as developed in Polk and adjacent counties has no definite terminal ridge answering to a moraine. Moranic patches are occasionally seen in neighboring counties, but in

*See La moraine terminal du Amérique du Nord; Compt. Rendu. Cong. Intern. géol., Paris, 1878; and Trans. Wis. Acad. Arts and Lit., vol. IV 1876-77, pp. 201-231.

†Geol. Iowa, vol. I, p. 98. 1870.

‡Geol. Nat. Hist. Surv. Minn., 1880, p. 293.

Polk county there is nothing whatever moranic or of the nature of a ridge about its border. The topography within the lobe is very different from that without. The drift within has also marked physical characteristics. But toward the border the drift becomes thin and the topography indistinct until it is often impossible definitely to locate the line. The outwash plain which might, from the known conduct of the Wisconsin drift in other states and the known presence of gravel trains be expected to aid in the discrimination, is rarely present. Around the end of Four Mile Ridge there is a certain development of sands and stratified drift, but this is a notable exception. In general the best field test is the presence or

FIG 56. Pond on Wisconsin drift at south end of kame near Kelsey

absence of loess at the surface. Where the loess has become covered by pebbly clay one is within the limit of the lobe, but where the loess forms the surface material the reverse may be assumed to be true.

The assorted drift found in connection with the Wisconsin drift sheet belongs to three categories, kames, gravel trains and gravel patches.

Kames are developed not at the immediate edge of the drift as is perhaps most commonly true, but are found some dis-

tance, ten to fifteen miles, back from the border. Two well marked kames are known; one immediately west of Crocker and a second about two miles south of High Bridge, or immediately east of the old town of Kelsey (Tp. 80 N., R. XXV W., Sec. 31). The Kelsey kame stands upon a drift plain which is about 150 feet above the river. This plain is fairly smooth, and is dotted with swales, some of which contain small ponds, one being represented in figure 56. Above this plain the kame raises forty feet. It forms an irregular ridge three-quarters of a mile long and a little more than one-quarter wide. At

FIG. 57. Kame near Kelsey.

its southern end, and partially separated from it, is an oval hill which does not rise quite so high. The upper surface of the kame is not smooth, but is somewhat hummocky. Its direction is not linear but sinuous. It is cut off rather abruptly at the ends, and the whole ridge forms a prominent landmark. Its general appearance from the west is shown in figure 57. In composition the kame is made up of Wisconsin material. Large bowlders are found on its surface and pits at three points show that to a depth of four feet at least it is made up of coarse water-laid gravels. Stratification is rude only. The pieces of gravel are one-half to three-quarters of an inch or more in diameter.

The Crocker kame stands among a group of hills which have a relief somewhat greater than is usual for this region. In form and dimensions it is very similar to the Kelsey kame. Its constitution can not be so confidently stated, but gravel is found over portions at least of its surface, so that it is presumed to be the same as in that of the Kelsey kame. There are other gravel accumulations in the county, particularly between Crocker and Polk City. They do not, however, assume the definite form associated with the term kame, and are perhaps best known by the more indefinite term of gravel patches.

The origin of the gravel patches and kames is doubtless to be referred to water which arose from the melting of the ice during its retreat. The definite form of the kame* is perhaps best accounted for by the influence of surrounding ice. So far as observed the one found in Polk county offers no new data upon which to base a conception of the details of the process of their formation.

One of the most obvious phenomena connected with the edge of an ice sheet is the presence of trains of gravels stretching down the rivers whose headwaters are cut off by the ice. That the diverging streams which depend upon the glacier should become loaded with gravel and should build terraces of that material stretching away from the ice seems in every way harmonious with the modern conception of an ice sheet and its work. This is, of course, possible only upon the hypothesis that the drainage be free and the rivers have sufficient velocity to carry the gravel for some distance. Free drainage as contrasted with a clogged drainage, such as has been suggested to have been prevalent at the time of the maximum extension of the Iowan ice sheet, means relative elevation; and the following of one by the other may be interpreted to mean a change in the altitude of the land.

In Polk county gravel trains are found along the streamways which lead out from the drift border. The gravel pits

*Chamberlin: Third Ann. Rep. U. S. Geol. Surv., pp. 307, 308. 1883.

of East Des Moines and farther down the river at Avon are in such a gravel train. Four Mile creek shows similar phenomena. Camp creek and Mud creek also have gravel terraces. In the counties farther west the Raccoon river bottoms are underlain by gravel. The gravel in all three cases is firm, hard material such as makes up the pebbles of the Wisconsin. Occasionally bowlders which might have come from the Kansan are also incorporated.

The gravel terraces are not conspicuous features. They are frequently covered with later alluvium, as at the Avon gravel pits, or rise ten to twelve feet above the modern bottom land, as at the newly opened pits in Highland Park. In this particular they differ from the gravel trains which are so characteristic of the Wisconsin drift in other states. In Wisconsin* the Green Bay glacier filled up the old valley of Rock river to a depth of 350 feet (including earlier drift) with a deposit of finely assorted sand and gravel, producing a level plain three to five miles wide and extending forty miles or more southward from the moraine.

The gravel trains in Polk county are found not only outside the area covered by the Wisconsin ice, but may in some instances be followed up the streams to well within the Wisconsin area. The gravel trains of Camp and Mud creeks are abruptly terminated at the upper end by the Wisconsin till. This is not, however, true of those of Four Mile creek and the Des Moines river. The pits recently opened by the Chicago Great Western railway at Berwick are about six miles within the limits of maximum extension of the ice. The Polk City pits are fully twice as far from the drift border, and the gravels occur along the Des Moines river well up toward High Bridge.

Along the Delaware river a somewhat similar series of phenomena occur. The explanation for them has been very carefully worked out by Salisbury.† The gravel train in that

* Chamberlin: Geol. Wis., I, 284. 1883.
† Ann. Rep. State Geol. N. J., 1892, 106-112. 1893.

case is not a single continuous train, but is rather a series of individual trains, each of which was formed successively farther up the river, and each corresponding to one of a series of moraines of recession. Apparently this explanation is equally good for the case in hand, except that here there are no moraines. The ice retreat seems not to have been by definite stages, but continuous. That there were minor stages in the retreat is, of course, altogether probable, and future detailed study may render it possible to discriminate them.

Belonging in a sense with the gravel trains, and yet to a certain extent differing from them, are the beds which have been represented on the map as stratified drift. They do not include all the stratified drift found in the county, since no attempt has been made to discriminate the gravel trains from the alluvium. Only those bodies of stratified drift have been represented which were of considerable extent and significance. These are confined to the old valley formerly occupied by the ancestor of the upper Des Moines river. As seen east of the capitol, this drift presents the characteristics common to outwash plains. It is sandy, mixed with gravel, and rises a little above the present bottom land. It has a slightly hummocky surface. The diversity of relief increases to the north, so that between Saylorville and Oak Park sandy drift hills of irregular form are common. In that portion of the valley which is now occupied by Beaver creek, the drift becomes more and more the normal bowlder clay, so that a short distance west of the county line the distinction between the two can not be drawn. In general it may be said that the drift of this valley is a bowlder clay deposited in the presence of considerable water. The anomalies are probably a result of the topography existing at the time of the ice retreat, the beds of material being in a valley 120 to 160 feet below the upland. Probably stagnant ice may account for some of the peculiarities.

ALLUVIUM AND TERRACES.

The extent of the alluvium is indicated upon the accompanying map with the correction that the terraces have not there been discriminated from it. It will be seen that alluvial bottom lands form no small proportion of the whole area. It will also be seen that the proportionate alluvial area is notably greater in the southern than the northern portion of the county. This becomes the more striking if the valley of the Skunk river, which is exceptional, be left out of account, and the comparison would be more striking still if it were possible accurately to map the small alluvial bottom lands found along the minor tributary stream-ways throughout the southern division. This distribution of the alluvium reinforces the argument derived from the drainage and topography for the relative youth of the northern portion of the county.

The alluvium forms a terrace along the streams. It is evidently a terrace of aggradation as defined by Salisbury.* Above it at many points along the upper Des Moines river, for example opposite the Sixth avenue bridge, near the Keystone mines, at the north of Beaver creek, directly west of Saylorville and near the mouth of Big creek, is a second terrace. This is made up of sand, gravel and gravelly drift, and seems to mark the stage where the Polk county gravels were laid down. It is essentially a gravel train, and its origin has just been discussed.

In the vicinity of High Bridge there are terraces which lie still higher. The main one is about fifty feet below the general upland surface and sixty-five to seventy feet above the river. It is about 300 feet wide and slopes back to the bluffs to such a degree that a small stream has located itself along the back of the terrace which is now in places six feet lower than the river edge. The side streams have cut away sharp gullies in this terrace, and the action has been so rapid that the divides between these gullies, even when less than six feet wide, remain flat topped. The material of the terrace

*Ann. Rept. State Geol. N. J., 1892, 103, 104. 1893.

is unstratified drift, and shows no trace of water action in its deposition. Twenty to twenty-five feet below the main terrace is a second, which is narrower and quite ill defined. These are along a portion of the valley less than half a mile wide. They are evidently not terraces of aggradation, but mark rather definite periods in the down-cutting of the stream, and hence correspond to the type discussed by Gilbert.*

Along the Skunk valley near Valeria is a low terrace which belongs to the second class.

ECONOMIC PRODUCTS.

Coal.

Polk county is one of the largest coal-producing counties in the state. In 1893 it stood second to Mahaska alone, but since then has been passed by Appanoose, where the coal lies nearer the surface and is more cheaply mined. The most productive portion of the Iowa coal measures consists of a long strip of territory running south from Fort Dodge and parallel to the Des Moines river. Polk county is about midway of this productive strip. The coal mined near Des Moines is mainly taken from seams lying at some depth, so that the area is neither so cheaply prospected nor is the coal so economically mined as in the counties to the north and south. Despite these facts mining has been carried on here since the first settlement of the country, and the coal industry is now a large and important one. At the time Fort Des Moines was occupied as a military post, coal was obtained from the surface vein still exposed near the Center street dam. For a long time this was the only vein worked, though it was opened up at a number of points both north and south of the river. Worthen,† as a result of observations made here in 1856, urged the propriety of sinking shafts to the lower seams which he indicated as present. It was some years, however, before this was done. The state census of 1856 records four miners

*Gilbert: Geol. Henry Mts., 126, 127. 1880.

†Hall: Geol. Iowa, I, 171. Albany, 1858.

in Polk county. In 1859 coal to the value of $337 was produced. In 1862, 35,468 bushels were mined. In 1865 the amount was 27,922 bushels, and in 1866 it had increased to 332,769 as a result of the opening of shaft mines. In 1867 the Watson Coal Co. sunk a shaft at the foot of Capitol Hill to the "first vein" of the east side, and for a long time this mine supplied the railroads. The Hall, Rawson, Reese, Dahl and numerous other mines in the meantime furnished coal from the surface seam. In the same year that the Watson mine was opened the Iowa Central shaft was put down on School street between West Fifth and Sixth. Apparently this shaft went only to the upper seam.

In 1873 Mr. Wesley Redhead resolved to open up the lower seams and the Des Moines Coal Co. was organized by him to sink a shaft on the south side opposite the present West Ninth street bridge. The shaft went down 150 feet to the "third vein," the "second" not being workable at that point. This mine, which was afterwards known as the Pioneer, was one of the most important in the district and worked out a large area, as is indicated on the sketch map (figure 47). Its success led to the opening of a number of mines in the vicinity, among which were the Sypher (1874), later known as the Polk County, the Eclipse (1873), the Pennsylvania, the Pleasant Hill (1875) and the Eureka (1875). About the same time or later the east side mines began to be opened up and mining was active there, particularly in the eighties. In 1893 the last of the east side mines, the Garver, was closed and the field deserted until the present season, when the new Eureka was opened.

In the earlier days, as has been seen, the upper vein was quite extensively worked north and west of town, but afterward the region was abandoned until 1893, when the newer group of mines now including the Keystone, Flint, Eagle, West Riverside, Bloomfield, Oak Park and Lake Park began to be opened up. West of the city the Two Rivers and other mines at one time took out coal, but the region has been abandoned for some years.

There has been a constant change in the center of minin activity, but it has been a change, not a loss. As individua leases were worked out the mines were closed, but new one have in almost every case been opened. In addition, nev capital has been coming in, new fields have been opened up and in some cases the deeper veins in abandoned portions o the field have been tapped. As a whole the industry has beei constantly growing. There have been periods of stagnation but these have been temporary, and for some time to come there will be opportunity for profitable mining, though the returns are not now so large as in earlier years. Here as elsewhere there has been concentration of capital, and a new order of things with larger dealings and a narrower margin of profit has developed. At present there are twenty-five mines in the county exclusive of the small drifts worked only for local trade and a few mines engaged in taking out the pillars and neglected blocks of coal in territory already worked by larger companies. According to the report of Mr. M. G. Thomas. State Mine Inspector,* there were in 1895 twenty-three plants operating on a commercial scale. These plants represented a capital of $430,000 and paid $329,190 in wages exclusive of the salaries of superintendents, mine foremen and other officials. If in addition to the capital invested in the plants the value of the lands undergoing development were to be reckoned, the total would me much larger. The output for 1895 was 334,881 tons, with a value of $458,707 at the mines. The small country banks were not taken into account in these figures and, while the amount of coal mined at each drift is small, the price paid is often relatively high, so that the value of the total output as given is low. Within the last year the industry has expanded quite notably. Old mines have been reopened for closer working, and many of the established plants have increased their working force.

A large amount of the coal mined goes on the home market. Very little coal is shipped into Des Moines, and the local

* Rept State Mine Inspector, 1895, p. 69

mines have a large trade to supply. The outside trade is growing, large quantities of coal being shipped north and west throughout Iowa and adjoining states. The exceptional railway facilities enjoyed by the mines of the city gives them a great advantage in competing for the trade of the northwest. One mine, for example, by means of two switches is able to ship over five of the main railway systems of the state without transfer charges.

The coals mined are bituminous and free-burning. They are not usually block coals, though there is occasionally a tendency in that direction. More frequently the horizontal lamination is most pronounced. The coals are quite firm and may, in most cases, be blasted from the solid. They make relatively little slack, and are of good quality for general steaming purposes. The percentages of ash and sulphur are about the same as in the average coals of the state. Even the fine coal is fairly clean, as is shown by the fact that it is the main boiler fuel throughout the city. Coking and gas coals have not been found to any extent. Occasional analyses of picked samples* show coal suitable for these purposes, but so far nothing of the kind has been developed on a commercial scale.

The following analyses, by Prof. G. E. Patrick, show the character of the coal as put on the market. The samples were not picked, but represent rather the average character of the coal. The percentage of ash is higher here than in much of the coal even in the same mines, and yet is probably fairly representative of the coal as marketed. At present the coal is nowhere cleaned except by screening. It is probably only a question of time until regular washing works will be erected in this direction. By their aid the ash can be almost wholly removed and the quality of the output proportionately increased. This will, of course, make it possible largely to expand the trade, since the cleaned coal is fully the equal in value of the eastern coals, which now have the advantage in

*Davis: Eng. Min. Jour., vol. LIX, No. 7, pp. 149-150. February 16, 1895.

much of the territory north and west of the Iowa fields. The difference in freight rates will more than offset the cost of cleaning, which has lately been very much reduced.

	Moisture.	Total combustibles.	Ash.	Volatile combustible matter	Fixed carbon.	Coke-fixed carbon plus ash.	SULPHUR.		
							Sulphides.	Sulphates.	Total.
Christy mine	6.10	82.59	11.30	39.06	43.53	54.83	4.99	.14	5.13
Gibson mine	7.04	82.89	9.72	40.06	43.17	52.89	4.09	.16	4.25
Manbeck mine	6.82	76.68	16.19	36.93	39.65	56.84	4.44	.29	4.73

The mining equipments are usually good. With the exceptions of a very few of the smaller mines, the Merchant and

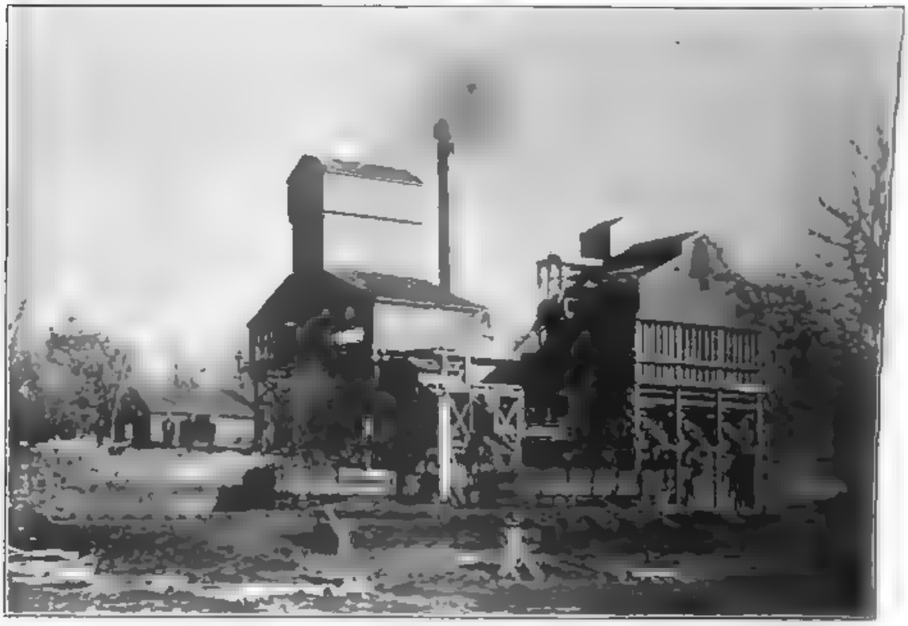


FIG. 58. Shaft house and tipple of Carbondale No. 2.

Hulme at Commerce, and some of the reopened mines of South Des Moines, substantial steam hoists are used throughout the county. In most of the mines mules alone are employed for underground haulage, but at the old Eureka and

the Christy tail rope plants have been installed. Sliding screens are most common, but there are a few mines equipped with revolving screens. There has been a constant improvement both in mining methods and equipment. The Carbondale mine No. 2, recently opened, is one of the most substantial and well arranged plants in the state. It is represented in figure 58.

This plant includes well built and well arranged top works, with revolving screen, chain conveyers, storage bins, extensive trackage and other features of a complete plant. At all the mines the cheaper types of boilers are used, and little attention is paid to economy in steam generation. The low price of fine coal which is used for fuel compared with the high cost of boilers of greater efficiency, together with the notoriously rough usage which machinery of any kind receives in coal mines, allows this system to prevail.

In mining, the work is all done by hand. Shooting from the solid prevails throughout the district, and the blast holes are drilled by means of the common hand drill with auger bit. Power has not been introduced in this work. At the Carbondale mines a power plant was recently put in. It includes both coal-cutting machines (Jeffery pattern) and drills. The machines were found to undercut nicely, but the blast left the coal in such shape that it was difficult to get it out, and the work has been discontinued.

The major development of the coal industry has heretofore been in the immediate vicinity of Des Moines, and here as elsewhere the mines have been located along the streams. It is believed that much of the remainder of the county will prove as rich as any which has so far been opened up. As has been shown in the preceding pages, the development of the streams was long posterior to the formation of the coal, and there are no known relationships between the two. The opinion sometimes entertained that productive beds are to be found only along the streams has no foundation except in the history of the industry where the coincidence is manifestly

the result of cultural factors. It is being constantly negatived as rapidly as prospecting is extended over the uplands, and the latter may be expected to prove as rich as the valleys.* These considerations enforce the belief that the industry in Polk county is in its infancy only, and that much the larger portion of the coal is yet untouched. Of a total of 375,200 acres within the county, about 8,000 only are now held for development by mining companies. In addition 2,200 acres have been more or less completely worked over so far as the known horizons are concerned. Much of the latter territory will not be reworked unless lower horizons should be located. A considerable portion, however, contains enough coal to be available for local mines.

In all less than six-tenths of one per cent of the area of the county has been worked out, even in the sense in which that term is used here. About 2.13 per cent is now being developed; 97.27 per cent of the region has not even been prospected.

It would be difficult to arrive at any estimate of the total amount of coal mined. Up to 1881, when the state mine inspectors were appointed, there was no agency for collecting and recording the statistics. The various census reports issued by the state give notes for the years of issue, but the intervening years are blank. In the following table the data so far as they are available are tabulated, the amount being recorded in short tons. The figures for the years 1881–95 are from the reports of the mine inspectors. Those for previous years are taken from the state census reports, except for 1860. The amount for that year is taken from the eighth federal census.

1856	600
1860	1,858
1862	1,418
1865	1,116
1866	13,310

* Since the above was written the extensive prospecting of the Consolidation Coal Co. over the highlands north of Des Moines has shown the presence of good coal at several points.

1869	27,796
1874	69,327
1881	473,893
1882	327,819
1883	558,821
1884	619,921
1885	462,895
1886	337,964
1887	305,094
1888	386,321
1889	356,039
1890	508,149
1891	397,833
1892	371,389
1893	466,408
1894	355,000
1895	334,881

The mine inspectors are restricted by law so that they take account only of mines employing more than four men. In 1893 the Geological Survey collected statistics of production from all the mines in the county and obtained a total of 693,103 tons. The year was notable for the exceptional output of Iowa mines, so that the ratio can not perhaps be fairly applied to the whole period, but if an allowance of one-fifth be made for the small mines the total coal mined since 1881 would be about 7,600,000 tons. The total amount mined before that time may be less accurately estimated at 2,300,000 tons. In round numbers Polk county has produced 10,000,000 tons of coal. As has already been indicated, only 2,200 acres have been "worked out," aside from the empty rooms in the mines now working. Since in mining practice about 3,200 tons per acre are, in this region, produced from a four foot vein, it may be estimated that about 3,000 acres have been mined out. Upon this basis the lands now prospected and under lease should yield approximately 32,000,000 tons. Whether or not the unprospected 97 per cent of the county will prove equally productive can not, of course, be foretold, but if it should prove very much less rich, Polk county would still have enormous reserves of coal within its borders.

The mines now operated are included in the following list. Their location is shown upon the map accompanying this report as well as in the small sketches introduced in the text. Since the stratigraphy of the coal measures and the distribution and character of the coal beds has already been given it only remains to note here the position and relations of the mines, together with a few details regarding the workings. The mines readily group themselves around eleven localities.

Runnells.—There are two mines in operation at this point. The larger is the Acme, which is a shaft mine with steam hoisting plant and a switch from the Wabash railroad. The coal is reached at a depth of forty feet and is the same vein which was formerly worked by a slope driven in from the bluff. The coal reached by the slope was cut by a preglacial erosion channel.* It was also cut off at the north by sandstone and shale which was drilled into to a depth of eighty feet without locating coal. The territory now developed is west of that mined by the slope and east of the territory which was worked out by the Midland mine, abandoned some time since. West of the Midland territory and north of town is the Star, a small mine worked for local trade. Still farther west, at the edge of the town, the Skandia mine was formerly located. About forty acres were opened up by this drift, but the work was abandoned because of fire.

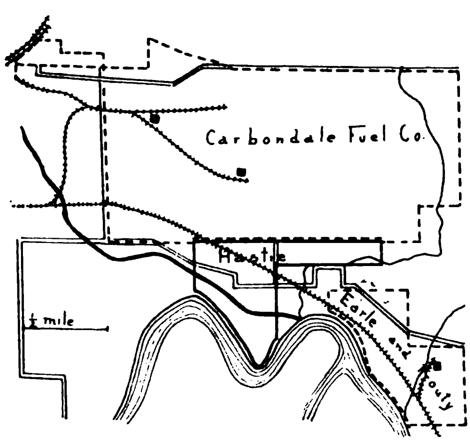


FIG. 59. Mines near Hastie.

Hastie. — A mine was sunk some years since at this point by Adams and Hastie. A four foot vein of coal was worked at a depth of 100 feet. Upon attempting to mine toward the south

*Keyes: Iowa Geol. Surv., II, 292. 1894.

water was encountered and the mine was eventually drowned out. A second shaft was put down farther east by J. M. Christy and a small area worked out. Near this point Earle & Prouty have a tract of land where the Iowa Fuel Co. now operates a mine. The shaft has a steam equipment and a track from the Wabash railroad. So far the output has been mainly used by the Newman Brothers' brickyard, which is located upon the same land. An upper seam of coal was worked to a slight extent by the Woodlawn Coal Co., but the shaft has been abandoned.

Manbeck.—Opposite Hastie is the mine of the Coal Valley Coal Co., which was owned formerly by the Manbeck and Coon Valley companies. The section as shown by mining operations has already been given. The coal now mined is reached by both shaft and slope. The upper seam, which is not worked, is reached by a slope driven up from the lower vein. This upper vein outcrops along the railway almost to Avon and has been opened up by local drifts at several points.

Carbondale.—The Carbondale mines form a group lying on the north side of the Des Moines river near Four Mile creek. They include the two mines of the Carbondale Fuel Co., the Christy mine and the two mines of the Gibson Coal & Mining Co.

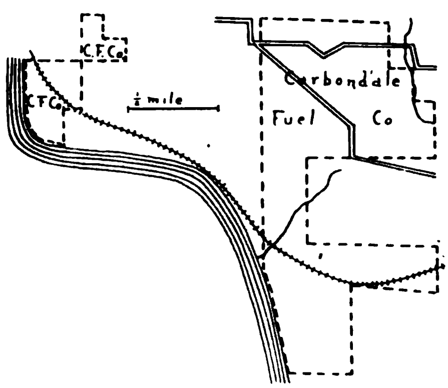


FIG. 60. Carbondale Fuel Co.

Mine number 1 of the Carbondale Fuel Co. was formerly operated by the Iowa Fuel Co. Number 2 is a new mine opened by the company immediately after its recent organization. Both mines are well equipped steam plants. The mines have connections with the Chicago, Rock Island & Pacific railway and the Des Moines Union, through which all the other roads in

the city are reached. The company has a large tract of land under lease at the mines, as well as two small tracts lying respectively south and east of the Earle & Prouty land, and a large tract near Adelphi (Tp. 76 N., R. XXIII W., Secs. 13, 24, 25.)

The Christy mine is located between the two tracks of the Chicago, Rock Island & Pacific railway, and works a large tract of land lying mainly to the west of the mine. It is a will equipped plant with a tail rope for underground haulage and a revolving screen for cleaning the coal.

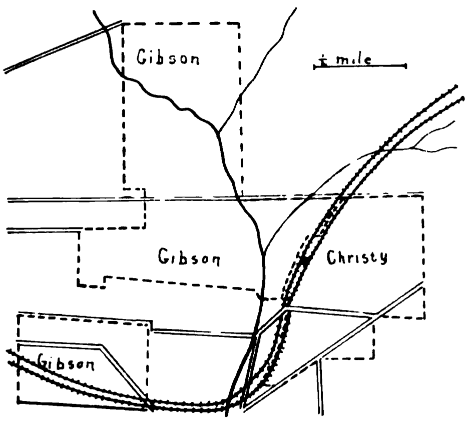


FIG. 61. Gibson and Christy tracts.

The Gibson No. 2 is a new mine located a quarter of a mile north of the Christy. It is also located between the two railway tracks. The land controlled by the Gibson company lies north and west of the shaft. In sinking the latter considerable trouble was experienced with a bed of quick sand. The section encountered showed the following beds.

		FEET
6.	Drift	12
5.	Sand	40
4.	Blue clay	4
3.	White pebble clay	5
2.	Black shale	22
1.	Coal	4

This differs in the upper portion very considerably from the record of a bore hole about 100 feet from the shaft. Since the mine is in the valley of Four Mile creek the explanation is found in the preglacial age of that stream.

Northeast Des Moines.—About three miles northwest of the Gibson No. 1, and likewise located upon the west flank of Four

Mile Ridge, are two mines, the Maple Grove and the Western. The Maple Grove is 105 feet deep, with coal three to four feet in thickness. The mine has a switch from the Chicago Great Western, but sells a large portion of its output on the local market. South of the Maple Grove was the Union, which worked out a tract of eighty acres and was abandoned. North of the Maple Grove is the new mine of the Western Coal Co., which has been opened up. A considerable tract of land has been prospected and leased, and substantial top works erected. Coal is shipped over the Chicago Great Western.

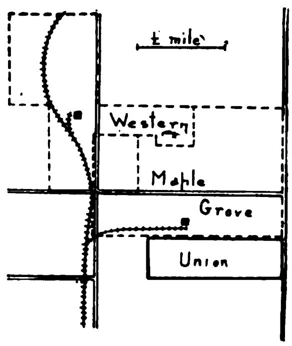


FIG. 62. Northeast Des Moines mines.

East Des Moines.—The only mine now operated in this famous mining district is the Eureka No. 2, which was opened in the fall of 1896. It is operated by the same company which owned the Eureka No. 1 on the south side of the river, and the mining equipment is the same. The company has a switch from the Chicago & North-Western railway. The strata found in sinking the shaft agree closely with those already given as found at the Giant mine. The thickness of the three veins as found here has already been given. The lowest vein is covered by twenty-five to thirty-four feet of back shale, so that the company anticipates no trouble from water. The company has 160 acres leased (Tp. 79, R. XXIII W., Sec. 36, Nw. qr.) of which a small portion only has been previously worked out by the Diamond mine. North of this lease (Sec. 25, Se. of Sw.) is the land mined over by the Miller mine. East of the Eureka (Sec.

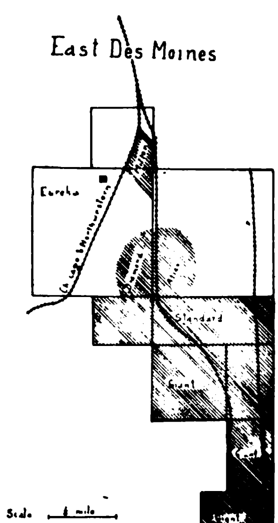


FIG. 63. East Des Moines mines.

36, Ne. qr.) is the old Atlas property, a very considerable portion of which was not mined because of trouble with water. South of the Atlas was the Standard (Sec. 36, N. ½ Se. qr.), and still farther south were the Giant mines (Sec. 36, Sw. of Se.; Tp. 78 N., R. XXIV W., Sec. 2, E. ½ of Ne. qr.). Directly south of the Eureka (Sec. 36, Ne. of Sw.) the Garver mine was located.

Saylor.—On the north side of the old valley previously described, the Des Moines Coal Co. have a mine near Saylor postoffice. The shaft record has been already given. The mine is connnected with the Chicago & North-Western railway. The lease includes 240 acres. The only other mining carried on in this vicinity was on the county farm. Over a portion of this land the upper seam shown at the Des Moines mine was worked out some time since.

Polk City.—But one mine has been open at Polk City. That is now owned by the White Ash Fuel Co. The shaft has steam equipment. So far local trade only has been supplied, but a switch from the Chicago & North-Western railway is to be built at once.

North Des Moines.—Along the Des Moines river from Sixth avenue to Beaver creek mining is being carried on quite vigorously. On the north side of the river are the Oak Park, Flint Valley and Lake Forest mines, of which the last two ship coal over the tracks of the Street Railway Co. On the south side of the river are the Bloomfield, Eagle, Keystone 1 and 2, and West Riverside mines. All of these mines are shafts, with steam hoisting plants, and all depend almost wholly upon the city trade. The Flint Valley furnishes coal to the brickworks

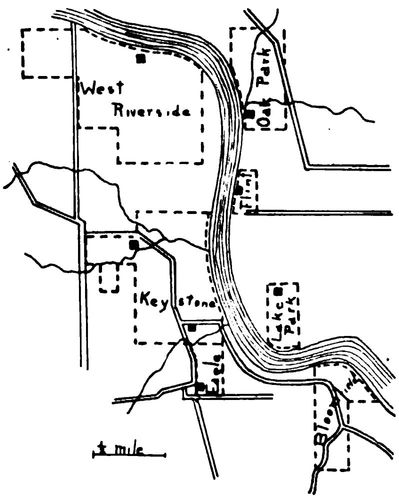


FIG. 64. North Des Moines mines.

of the same company, while the Keystone mine and the Iowa Brick Co. use the same territory.

South Des Moines.—At present there are but four mines in South Des Moines which are opening new territory. These are the Clifton, Proctor and the two mines of the Van Ginkle Coal Co. All are shafts operated by steam power. In addition, coal is being taken out from the second horizon on the land formerly worked by the Polk County and Des Moines mines by small gin shafts. The Riley mine, a small gin shaft, is located near the Des Moines.

The Scott mine is a small drift worked in the first vein upon the territory of the Pennsylvania. All this territory is, however, in the main, worked out, and the mines now operating obtain coal from areas neglected by the older mines. The Van Ginkle mines, one of which is now known as the Pleasant Valley mine, have a switch from the Chicago, Rock Island & Pacific railway. (See figure 47.) The Clifton and Proctor mines have no railway connection. The Clifton mine is located on Clifton avenue, at the top of the hill leading up from the Raccoon. South of it a half mile is the Proctor. Between the two is a small strip of territory worked out by the Bloomfield. Between the Proctor and the Bloomfield is a "fault" towards which the coal rises and thins. It has been worked into 200 feet without being crossed. The Bloomfield lease lay east of the Clifton and Proctor. Beyond it was the half section controlled by the Eureka. East of the Eureka lease is the Van Ginkle land. Next to it is a strip worked out in part by the Polk County, and in part by the Des Moines mine. Beyond the latter was the Eclipse lease, and in part south and in part east of the Pennsylvania. The Pioneer land lay north of the Bloomfield and Clifton, and in part west of the Eureka. It extended north beyond the river. West of it was the Coon Valley, and near the latter a small area was worked out by the Great Western Coal Co.

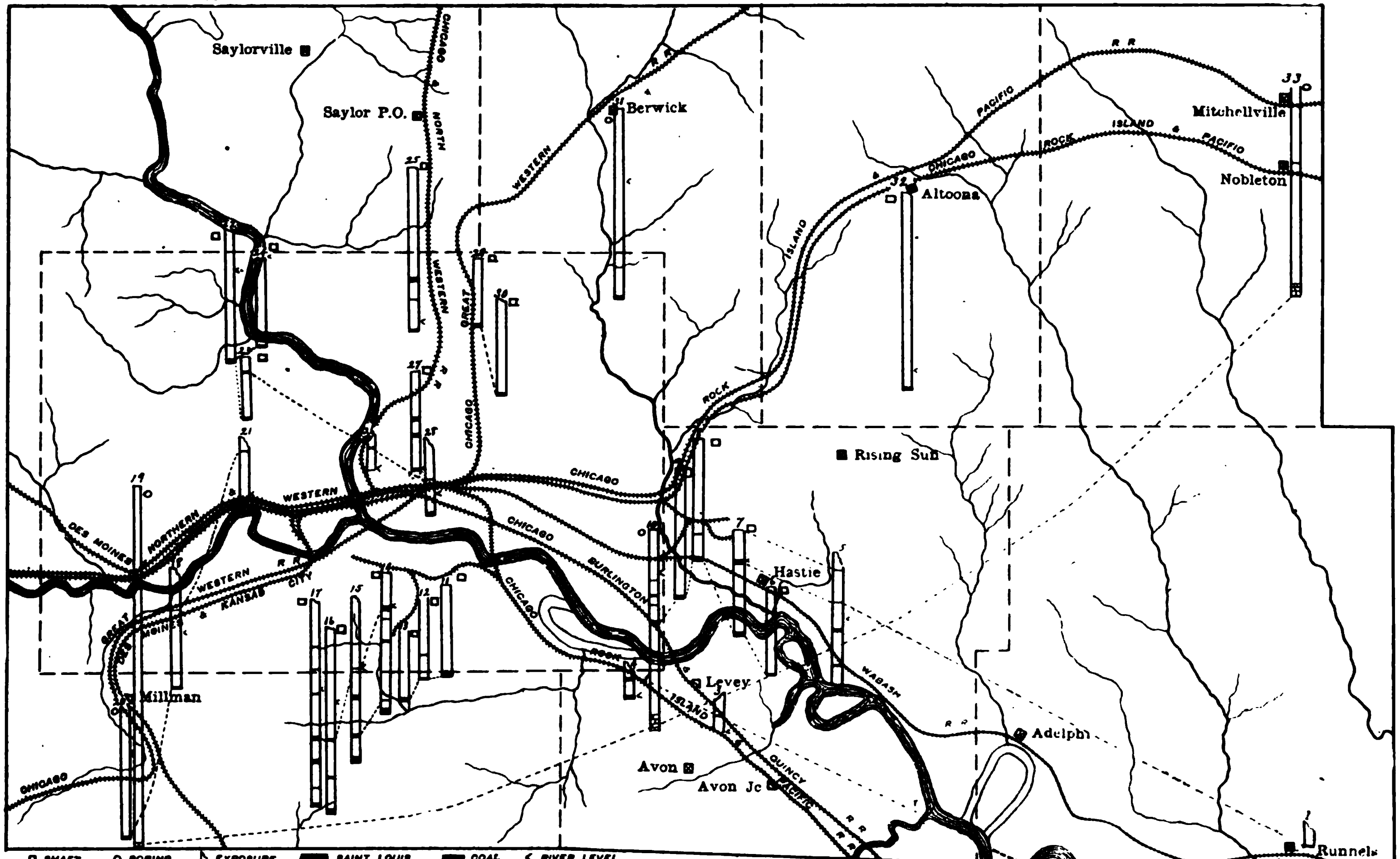
Commerce.—There are two mines in operation at Commerce, both of which are gin shafts, and both of which sell only to

the local trade. The Merchants mine has a lease of forty acres at the western edge of town north of the river. The Hulme mine is just east of town. The land owned here by Dr. Hulme includes 240 acres, part of which is south of the river. It has been prospected and shown to contain coal.

In connection with the sketches showing the location of the mines plate ix may be studied. Upon this plate the coal beds shown at the principal exposures, or found in mines or borings, are represented. The details of the sections have been in most cases given in the descriptive portion of this work. The correlations, so far as they can be made, are indicated by the dotted lines. Where they are not indicated the probable correlations may be inferred from the relations of the coal to the river level. The basis of the correlations has been already discussed. The plate shows graphically much of the evidence upon which they are based, as well as the difficulties which are encountered in any attempt at detailed correlations. It will be noted that the coal beds of the southeastern portion of the county form one group; those of South Des Moines form a second; the East Des Moines, and along the river to the Beaver, are readily correlated, and the sections near Millman fit together; but between these separate groups correlation is less easy, and for reasons already given, has not been attempted. The great irregularity in the surface of the Saint Louis is brought out, as is also the irregularity of the present topography. The thickness of the coal beds is necessarily exaggerated. Their distribution and vertical relations are better indicated.

Clays.

Des Moines is rapidly becoming known as one of the great centers for the manufacture of clay goods. It already manufactures more paving brick than any point west of the Mississippi, and the whole clay industry of the county is yet in its infancy. Polk county contains vast quantities of material suitable for manufacture into all grades of clay goods, and



1, Acme.
2, Ford.
3, Avon.
7, Carbondale.
8, Gibson.
9, Christy.
10, Crescent.
13, Van Ginkle,
14, Eureka I.
15, Bloomfield.
16, Proctor.
19, Greenwood Pk
20, Millman.
21, Terrace Hill.
22, W. Riverside.
23, Eagle.
24, Oak Park.
25, Des Moines.
26, Tile works.
27, Eureka II.
28, Capitol Hill.
29, Maple Grove.
30, Union.
31, Berwick.
32, Altoona.
33, Mitchellville.

while at present the output is limited, it may be expected to expand with increasing demand.

Both the coal measures and the Pleistocene beds yield material suitable for manufacture. The loess is at present used mainly for the common grades of brick, but it is so abundant, so easily worked, and is capable of yielding such excellent results, that it may be expected to be brought more and more into requisition. The alluvium is quite generously developed along the streams, particularly of the southern portion of the county, as is shown upon the accompanying map. While it is in places quite thin, and forms merely a sheet over underlying gravel or till, the aggregate amount present is enormous, and at any given point is far in excess of any probable demand.

Alluvium is one of the most easily manipulated of clays. It usually occurs with about the proper proportions or silica and other ingredients, so as to require no mixing with other material. It is spread over flat land, and hence is readily accessible. It is easily dug and requires no crushing. It will stand, in most instances, sun drying, and is most commonly burned in simple cased kilns. By the hand process, when properly carried out, it yields an excellent brick of fair strength, good color and low cost. The sand-rolled brick made from alluvium are not so beautiful as more expensive brick, but they are equally well adapted to inside work and all classes of construction when fair strength and low cost are the main considerations. There must always be a good demand for such brick, and Polk county is well supplied with material for all such local and probable foreign demand.

The second class of Pleistocene material available is the loess, whose properties and distribution have already been discussed. The loess occurring near Des Moines is mainly of the type which for want of a better name is known as typical loess, to distinguish it from the phase called white clay. It is highly silicious, contains considerable lime, and allows a freer circulation of water than the white clay. The loess

A most important factor in the life of a pavement is the character of the roadway upon which it is laid. It should be well drained and well packed. In Des Moines the brick are laid in either single or double course. The single course brick rest upon a concrete (six inch) or macadam (five inch) foundation, with the brick set on edge with their longer diameters across the street. Between the brick and the concrete is a two-inch cushion of clear sand. When the brick have been set in place fine gravel and coarse sand are brushed over the surface, so as to fill the interstices, and hot pitch is run into the seams. A top surface of fine sand is spread over the pavement and allowed to remain for a few days, after which it is brushed off. Double course pavement is not ordinarily laid on concrete. The ground is prepared by grading and rolling, and a course of hard burned brick laid over sand. Above this is a second sand cushion, on which the paving brick are laid, as in single course work.

One course paving requires sixty-six brick and costs with concrete according to recent contracts, $1.35 to $1.68 per yard. Two course paving requires 105 brick and has been costing, with concrete, about $1.25 to $1.50 per yard. It is impossible to compare these figures with the cost of other work, since nothing but brick has been laid in Des Moines in recent years. At Minneapolis recent bids were $1.85 for one-course brick and $2.51 for asphalt.

For very heavy traffic streets the foundation should be strengthened. The Michigan avenue work in Chicago consists of one course brick over sixteen to eighteen inches of crushed stone and concrete. For such streets only the best brick should be used. While clays capable of being manufactured into average paving brick suitable for residence streets and smaller cities are not rare, clays which yield the higher grade of pavers are not so common. For heavy traffic streets or steep grades only the finest quality of material should be used. Even such material will probably not be so long lived as well selected granite blocks, but the first cost is very much

and drain tile, and common pottery, and have been proven by careful experiment to be well adapted to the manufacture of certain classes of terra cotta and pottery. The differences in appearance and texture of these clays have been noted in the sections given on preceding pages. Their wide distribution may be inferred from the same data. Certain minute differences and adaptabilities as at present known are noted in the sections which follow. The coal measures are used largely in the manufacture of pavers and various grades of building brick.

Of pottery only the coarser grades are now made. There are no kaolin deposits in the region, so that if the finest wares be attempted kaolin must be imported and mixed with the local clay, which may be used as a base. Since, however, this is advantageously done at other points, it is to be expected that in time the local demand at least will be supplied by the home product. An excellent grade of kaolin has been for some years supplied from southeastern Missouri to Ohio, where it is used in connection with coal measure clays in the manufacture of medium and fine pottery. There seems to be no good reason why a pottery industry similar to that of Ohio should not be built up in Iowa. The coal measures of this state contain beds of clay well adapted to this use and the Missouri kaolin deposits are nearer Iowa than Ohio.

In this connection it is of interest to note that the Carbondale Fuel Co., as a result of experiments made both in this country and in Scotland upon clays found upon their lands, have shown that their clays are not only suitable for the paving and various colored building brick already manufactured within the state, but are adapted for enameled brick and probably for ware of finer grades. It is expected that plants will be erected for manufacturing these various lines of ware.

One very important use for clays of the grade found here is the manufacture of sewer pipe and chimney tops. At pres-

ent there is but one plant in operation, but the business is one which may be expected to expand.

In general, it may be said of the clay industry of Polk county, that there is room for great expansion. With inexhaustible quantities of clay of such widely varied adaptabilities, with coal at hand, and with exceptional transportation facilities, the region must become famous for its clay products. There will always be a considerable local demand to be met, and so long as clay goods are shipped into the state there will be trade to be won by local companies.

The methods adopted in working the clays vary with the material, the object to be attained, and the individual preference of the operator. They are brought out in the descriptions of the individual plants.

PAVING BRICK.

Among the most important industries of Des Moines is the manufacture of paving brick. This industry is of recent establishment, and its rapid development is very gratifying. Paving brick have been used in Holland for more than a hundred years, but the use of brick for street paving in the United States is quite recent. In 1870 an experimental block was laid in Charleston, W. Va., and in 1873 several blocks were laid in the same city. These brick are still in good condition in spite of having been laid upon a board foundation and of being of inferior quality, as judged by present standards. At Bloomington, Ill., several blocks were laid in 1875, and have stood twenty years of service. These were merely hard burned building brick, and much inferior to the modern pavers. It was not until 1890 that the paving industry showed any notable tendency to expand, but since then its development has been very rapid. Brick paving is being gradually introduced into the larger cities. Saint Joseph began to use it in 1888, Kansas City adopted brick paving in 1889, and Saint Louis in 1895. Paving brick are now being used for residence streets in Philadelphia, and more recently brick

have been laid in Minneapolis, Omaha and several other cities. In Chicago a few residence streets are paved with brick, and experimental blocks have been put down by the Purington Brick Co. on Michigan avenue and the Des Moines Brick Co. on La Salle street.

In Des Moines the first brick was laid in 1889. They came from Saint Joseph, and were laid on Forest avenue. The first pavers made here were turned out in 1891 by the Des Moines Brick Co., and were used with outside brick. The first brick paving done exclusively with Des Moines brick was in 1892, when East Grand avenue to the fair grounds was paved with brick furnished by the Des Moines Brick Co. To this company is largely due the credit for demonstrating that the shales found here could be made into pavers second to none. Since the first success the industry has rapidly expanded until now four large paving brick plants are in operation, and others are contemplated. The brick is used at home so extensively that Des Moines is becoming known as the city of brick-paved streets, and is gaining an enviable reputation for its fine driving and haulage ways.

Brick paving has of recent years become rapidly popular. It has, as compared with other forms of paving, many important advantages, among which may be mentioned the fact that it is clean, nearly noiseless, healthful, smooth, durable and cheap. When properly laid it has always exceeded expectations. A not unimportant advantage of brick paving is the fact that it allows the cleaning of the streets by flushing, particularly if the sewers be made of the same brick, and so are not affected by the wearing action of the muddy water. Brick paving is easily and cheaply repaired, and like granite blocks, is easily torn up for the purpose of laying or repairing tracks, pipes, conduits, etc. It is less noisy than granite, and since it forms a more even surface, is cleaner. It is not slippery like asphalt, and is much more durable as well as more healthful than the wooden blocks.

less, and the difference in noise and resistance to traction offsets the shorter life of the pavement. In the latter particulars brick is only exceded by asphalt which, however, can not be used on grades of over five per cent, can not be flushed, and is expensive both to lay and to keep in repair. The only cheaper pavements are the Macadam and Telford, which require constant care and repairs.

The durability of brick paving has not yet been determined. No first class pavers have yet been worn out and some of inferior quality have stood hard service for more than twenty years. From the evidence of the last ten years it seems probable that well made and well laid brick are only surpassed in durability by granite blocks. The popularity of brick paving in Iowa and the central west is established by the fact that Des Moines brick are now in use in Chicago, Minneapolis, Saint Paul, Omaha, Council Bluffs, Dubuque, Cedar Rapids, Waterloo, Marshalltown, Davenport, Muscatine, Keokuk, Iowa City, Waverly, Adel and other cities. In 1896 18,000,000 pavers were sold, and for 1897 the home orders alone call for about 7,000,000.

The paving brick industry is so new that its technology is still in the process of development. It is only within the last few months that even a uniform series of tests has been formulated, and improvements in the process of manufacture and burning are constantly being introduced. The reported failures of brick in some of the early experiments are now known to have been as often the result of improper selection and lack of familiarity with the proper methods of laying brick, as of the poor quality of the brick itself. The quality is, however, being constantly raised as the requirements are better understood and the properties of the clays are more studied.

The most valuable treatise on the manufacture of paving brick is that recently issued by the Missouri Geological Survey* and written by Prof. H. A. Wheeler, of Washington

*Mo. Geol. Surv., vol. XI, 622 pp., 38 pls. Jefferson City, 1897.

University. The report covers all of the clay industries of the state, and from the chapter on paving brick clays much of the following is condensed. According to Professor Wheeler a vitrified brick is one that is burned so hard as to be almost non-porous. It should have a close, dense, compact structure, a very high degree of hardness, and the individual particles of the clay should be no longer visible, even with a lens. In Des Moines practice brick are accepted for street use if upon a chipped surface it does not show individual grains. Since all such tests are matters of degree, and since the quality of the brick has been amply attested both by use and experiment, this seems to be a safe test.

If the brick are cooled slowly they will have a crushing strength that exceeds granite and a toughness nearly as great. In these particulars they are sharply differentiated from building and fire brick. If they are burned so hard as to be completely vitrified they are glassy and are not so tough. The lower heat only slightly vitrifies the material and produces a brick with stony fracture. It is this "incipiently vitrified" brick which is desired. The materials used for paving brick are shales and impure fire clays. The primary requisite is ready fusibility which is induced by what are called the fluxing impurities, iron, soda, potash, lime and magnesia. The greater the amount of the first of these constituents the easier it is to fuse the material. The Des Moines clays carry from 2.05 per cent to 13.12 per cent of this material, and the percentage of total fluxes varies from 2.88 to 17.60, the majority falling between 6 and 10 per cent. The extremes are of course only used in combination. The clays as mixed and put into the pug-mill carry according to one series of determinations 7.48, 6.13, 10.52 and 5.53 per cent of fluxes. The higher percentage of fluxes has the advantage of causing vitrification to set in at relatively low temperatures and hence allows fuel economy. Too high a percentage, however, causes too ready a fusing, and yields glassy brick which fail in toughness.

The toughness of brick seems to depend largely upon the physical properties of the clay, including particularly the fineness of grain and the density. It is also influenced very largely by the manipulation of the clay and the manner of the burning.

The chemical composition of the shales used for paving brick shows the widest variation. This is illustrated in the analysis of the Des Moines shales, and in the following table given by Wheeler, and based upon fifty carefully selected analyses.

	Minimum per cent.	Maximum per cent.	Average per cent.	Total averages.
Silica ($Si O_2$)	49.0	75.0	56.0	......
Alumina ($Al_2 O_3$)	11.0	25.0	22.5	......
Ignition loss ($H_2 O, S, CO_2$)	3.0	13.0	7.0	......
Moisture ($H_2 O$)	0.5	3.0	1.5	......
Total non-fluxing constituents	......	......	......	87.0
Iron sesquioxide ($Fe_2 O_3$)	2.0	9.0	6.7	......
Lime ($Ca O$)	0.2	3.5	1.2	......
Magnesia ($Mg O$)	0.1	3.0	1.4	......
Alkalies ($Na_2 O, K_2 O$)	1.0	5.5	3.7	......
Total fluxing constituents	......	......	......	13.0
Grand total	......	......	......	100.0

As a matter of fact the majority of clays used approximate quite closely to the average given. The wide range in composition is possible because of a compensating range in the manner of combination of the fluxing constituents and in the specific gravity and fineness of grain.

The requisite physical properties are summarized by Wheeler as follows.

(1) The clay should have sufficient plasticity to allow it to be readily moulded. If it is so lean as not to admit of being worked into a continuous bar by an auger machine it cannot compete in cost and quality with the clays that can be so

worked unless a fat or bond clay is mixed with it. The air dried clay should have a tensile strength of about 100 to 150 pounds per square inch. If it is too fat, or the tensile strength be above 200 pounds, the clay is apt to laminate in moulding and check in drying. The checking can be prevented by mixing in lean clay, grog or sand, but the resulting brick are never so strong, and there is danger of lack of uniformity in the brick as a result of imperfect mixing.

(2) The shrinkage in air drying or burning should not exceed 12 per cent. Greater shrinkage leads to checking and increases the difficulty of burning.

(3) The clay should allow the brick to be put through a properly constructed dryer in twenty-four to thirty-six hours. Slower drying causes delay and extra expense for added drying room.

(4) The speed in burning should permit a vitrifying heat to be put on in five or six days. A tender clay, demanding slow firing, greatly increases the cost.

(5) The point of incipient vitrification to which all paving brick should be brought should be low, from 1,500° to 2,000° F. It should be readily obtained in an ordinary kiln.

(6) The point of viscous or scoriaceous vitrification should be at least 300° and preferably 400° F. above that of incipient vitrification. Unless there is an ample margin there is heavy loss from either soft unburned, or warped overburned brick. It is impossible to control the heat of the kiln within a very narrow margin.

(7) The density both before and after burning should be as high as possible, since it is an important factor of durability.

(8) It is often desirable, in order to meet a popular prejudice which seems to have some foundation in reason, that the clay should burn to a dark color.

The quality of the output is very largely influenced by the character of the process of manufacture adopted. The details of the process as carried on in the Des Moines plants are given in the descriptions of the individual works. In general the pro-

cess includes (1) mining of the clay, (2) pulverizing, mixing and tempering, (3) moulding the brick, (4) drying, and (5) burning. Thorough pulverizing and mixing is important to secure a homogeneous product. The tempering controls largely the ease of moulding, drying and burning. In this work, because of the uniformity which may be attained by its use, the automatic tempering machine used by the Iowa Brick Co. has many important advantages. In moulding it is important to avoid excessive lamination since this is particularly unfortunate in paving brick. The amount of lamination may be controlled by proper tempering which may be in turn controlled by regulating the feed of the machine.

Recently it has become common to repress the brick. This process gives them better shape, makes them denser and usually stronger. In drying the usual care must be exercised to avoid checking, which is particularly liable to occur in paving clays because of their considerable shrinkage. The burning is perhaps the most important part of the process. In this work down draught kilns are exclusively used. The bricks should be set very open and the heat thrown first to the center. As color is not important water-smoking with wood is unnecessary and the whole burning may be done with coal. After the water-smoking two to four days, firing should be maintained four to six days, so as to bring the entire kiln up to a cherry red heat, 1,600° to 1,900° F. The kiln should be cooled slowly allowing plenty of time, six to twelve days, for the annealing. The slower the cooling the tougher will be the brick. It is impossible to burn a uniform kiln of brick. Only from 60 to 90 per cent will be No. 1 quality. At Des Moines the percentage ranges usually from 75 to 85 per cent. The remaining brick, while unsuitable for paving, are excellently adapted for use as hard burned building brick and usually command a ready sale.

The testing of paving brick is a matter which has attracted much attention, and the proper methods of testing have been much misunderstood. An experienced inspector can tell

much from the appearance of a brick and the character of a fractured surface. He may, however, be much deceived in examining brick with which he is not familiar, and in any event such a test can not be formulated so as to be either useful for comparison or available for future reference. A number of mechanical tests, including crushing, cross-breaking, absorption and the rattler test have been used. The present tendency is to rely mainly upon the eye inspection and the rattler test.

The paving brick companies of Des Moines have recently had a very complete set of tests made upon their brick. The work was done by Mr. E. P. Boynton, C. E., city engineer of Cedar Rapids, with the exception of the chemical analyses which were made under his direction by Prof. C. O. Bates of Coe College. The tests were carefully planned and were carried out with great detail. Through the courtesy of the managers of the four companies concerned, the Survey is permitted to publish here the summary results of the tests. It should be remembered that these are only the summaries and in each case represent a large number of individual tests. A few of the detailed tests are given under the description of the individual plants. At this place, in Table I, is given a general summary, together with the results of similar tests on certain other well known brick for comparison.

TABLE I.

PAVING BRICK TESTS—GENERAL RESULTS.—E. P. BOYNTON, C. E.

NAME OF MANUFACTURER.	METHOD OF MANUFACTURE.	ABRASION AND IMPACT, RATTLER TEST.			Porosity. Absorption.	TRANSVERSE STRENGTH RUPTURE.			Comparative rating by formula.
		AVERAGES.							
		PER CENT OF LOSS.				MODULUS OF RUPTURE.			
		Actual.	Rational.	Average of 3 and 4.	Per cent of gain.	Actual.	Rational.	Average of 7 and 8.	
1	2	3	4	5	6	7	8	9	10
Diamond Brick & Tile Co., Kansas City, Mo.	End cut	----	----	----	----	----	----	----	----
	Common	15.17	15.17	15 17	.71	2,190	2,190	2,190	62.14
Purington Brick Co., Galesburg, Ill.	End cut	----	----	----	----	----	----	----	----
	Repress	9.09	9.09	9 09	1 85	3,365	3,365	3,365	104.14
Galesburg Vitrified Brick Co, Galesburg, Ill.	End cut	----	----	----	----	----	----	----	----
	Repress	11.89	11.27	11.58	1.05	3,122	3,122	3,122	90.70
Des Moines Brick Manufacturing Co., Des Moines, Iowa	End cut	11 07	11.07	11 07	.93	2,584	2,584	2,584	89 36
	Common	12.80	12.13	12 49	1.17	2,621	2,621	2,621	80 39
Capital City Brick & Pipe Co, Des Moines, Iowa	End cut	17.78	17.61	17 70	.54	3,896	4,080	3,988	62.89
	Common	12 49	12.49	12 49	.60	3,429	3,429	3,429	89.82
Iowa Brick Co, Des Moines, Iowa	End cut	12 28	11.45	11.87	.80	----	----	----	80.61
	Common	16.80	15.65	16.23	.86	2,193	2,193	2,193	54.21
Iowa Brick Co, Des Moines, Iowa	Side cut	12 23	11.81	12 02	.55	----	----	----	92 12
	Repress	14 80	13.63	14.22	.96	3,348	3,714	3,531	77.28
Flint Brick Co., Des Moines, Iowa	End cut	----	----	----	----	----	----	----	----
	Common	12 49	12 49	12.49	.93	2,740	2,740	2,740	82.25
Davenport Paving Brick & Tile Co., Davenport, Iowa	End cut	----	----	----	----	----	----	----	----
	Common	15.03	14.67	14.85	.93	2,056	2,056	2,056	61.88
Ottumwa Paving Brick Co., Ottumwa, Iowa.	End cut	----	----	----	----	----	----	----	----
	Common	12.95	12.95	12.95	2.10	2,343	2,343	2,343	71 20

The tests included the determination of the abrasion and impact loss by means of the rattler, the porosity by the absorption test, and the transverse strength. The latter is expressed in terms of the modulus of rupture. The rattler used was polygonal in form, twenty-nine inches in diameter, and forty-eight inches long. It was charged with eleven brick and a standard charge made up of 300 pounds of two-pound cubes, 340 pounds of two-pound cast iron spheres, and 120 pounds of smooth cast iron foundry shot one-fourth to one-half pounds each in weight. This charge was itself determined to be best adapted to the work as the result of a series of experiments. The test consisted of 800 revolutions at a rate of thirty-three revolutions per minute, the rattler being driven by steam. The loss is calculated in per cent by weight.

The absorption test was made upon brick which had been subjected to the rattler treatment and had accordingly lost their external glaze. The brick were brushed clean, dried at 174°–178° F. for seventy-two hours, cooled one hour at 60° F., weighed to .0025 pounds, set on edge in running water at 40°–42° F. for seventy-two hours, wiped dry with a cotton cloth and re-weighed. The gain is expressed in per cent by weight.

The transverse strength was tested by cross-breaking and from this the modulus of rupture was calculated as usual.

The formula used for calculating the general rating was adapted from one used by Wheeler. It is as follows:

$$V=(20-R)\,6 + (8-A) + \frac{T}{110}$$

R=Rattler loss in per cent by weight.
A=Absorption in per cent by weight.
T=Modulus of rupture per square inch.

The actual ratio in each case was obtained by comparing all the specimens tested. The rational ratio takes account only of those which show no signs of having suffered accidents during the tests.

Des Moines Brick Manufacturing Co.—This company was the pioneer in the paving brick industry of Des Moines. They formerly operated a small plant for the manufacture of tile, but in 1891 undertook the manufacture of building

brick and pavers. The first large contract which the company filled was to furnish the brick for the Equitable building, both the face and roof brick being furnished. Later they began to make pavers as already noted. Their success has been to a high degree gratifying, and the original plant has grown until it is now one of the largest brick plants in the west. The works are located in west Des Moines between the tracks of the Chicago, Rock Island & Pacific and the Des

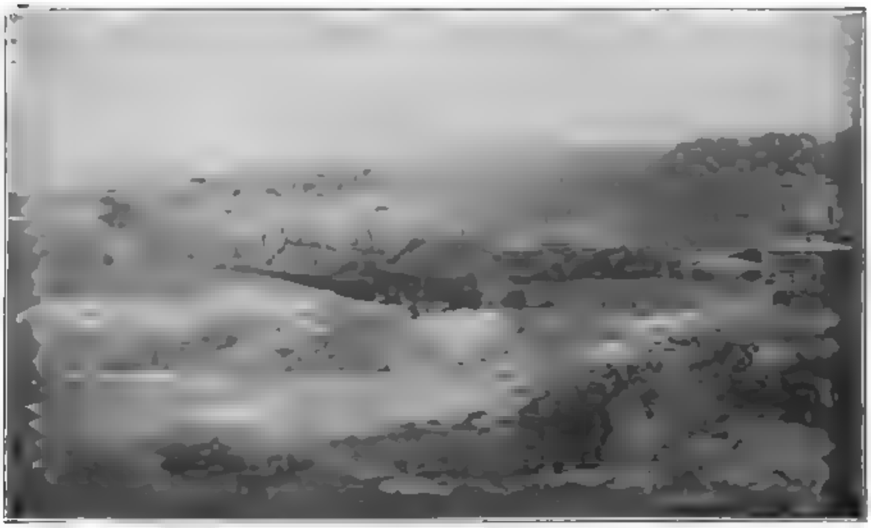


Fig 63. Des Moines brick works.

Moines & Northern railways. A considerable portion of the output was at first placed on the local market, but of recent years the shipping trade has been increasing. The pit is in all about forty-five feet deep.

The clay, as exposed at the time of Mr. Boynton's tests, and character of the brick which may be made from each stratum is given below.

D—1. Clay, variegated, highly refractory, burning to a brick of medium toughness, high porosity and low breaking strength; thickness, three to eight feet; average, five feet.

D—2. Shale, streaked in color, medium fusibility, high in iron and fluxes; burns to a brick of medium toughness, medium porosity and low resistance to rupture; thickness, three to eight feet; average, four feet.

TABLE IV.

DES MOINES BRICK MANUFACTURING CO.

ABSORPTION TEST.

General pavers, end cut common, from brick for paving Union station grounds, Cedar Rapids, Iowa, in 1896, made in 1895. E. P. BOYNTON, C. E.

MARKS.	WEIGHT IN POUNDS.		Gain.	Per cent of gain
	Dry.	After immersion		
D-6-II	4.95	4.97	.040	.90
D-6-V	4.36	4.385	025	57
D-6-T	4.80	4.82	020	.41
D 6-L	5,09	5.11	020	.39
D-6-IX	4.87	4.90	.030	.61
D-6-X	4.82	4.845	.025	.52
Average				.56

TABLE V.

DES MOINES BRICK MANUFACTURING CO.

TRANSVERSE RUPTURE TEST.

Broken in registering hydraulic press. Modules of rupture $= M = \frac{3\,l\,w}{2\,b\,h^2}$ in which l = length between supports, = 6 inches, b = breadth and h = depth of brick, w = breaking load

General pavers, end cut common, from brick for paving Union station grounds, Cedar Rapids, Iowa, in 1896, made in 1895

E. P. BOYNTON, *C. E.*

MARKS.	b.	h	w	m.	REMARKS
D-S-I	4.05	2.40	7,000	2,695	Medium dark reddish.
II	4.02	2.38	6,200	2,453	Brown color, with many white and red pebbles
H	4.00	2.35	6,900	2,810	Few lamination cracks
Z	4.10	2.32	5,600	2,291	Break on two or three edges.
V	4.11	2.35	7,200	2,856	With square even fracture.
Average				2,621	

The figures given in tables III, IV and V are obtained from tests made on the general paving brick manufactured by the company. A combination of the results according to the general formula, $V = (20 - R)\,6 + (8 - A) + \frac{T}{110}$, gives a rating of 101.95, a most satisfactory showing. The ratings given in

The clay is mined by means of a Barnard steam shovel which loads the material into small cars. The latter are hoisted and dumped, the material falling into the dry-pans, one of which is of the Eagle Iron Works pattern and the other that of the Des Moines Manufacturing & Supply Co. The crushed clay is conveyed by an elevator to screens with openings $\frac{3}{4} \times \frac{3}{16}$ inch, and thence to bins. A portion of the material is pugged in a Wallace mill, and the remainder passed through a Chambers pug-mill. Two Chambers brick machines are used in moulding. They have a combined capacity of 70,000 brick in ten hours. Four Eagle represses are used. The bricks are loaded at the machines into iron cars, upon which they are pushed through the dryer to the kilns. The dryer has six tunnels and is held at 230° to 300° F. It takes thirty-six to fifty hours to dry the brick. In burning, Eudaly kilns, of which there are ten, of 200,000 to 225,000 capacity each, are used. Water-smoking consumes two to three, and the burning takes about six days. The brick have a high and well deserved reputation, as is shown by the subjoined tests. They have been used in most of the important paving contracts filled by Iowa contractors. When the works are in operation the out-put is about 120,000 per day with 80 to 85 per cent pavers. In all, about 76,000,000 paving brick have been made at this plant. It takes about thirty days to get the plant fully in operation.

TABLE III.

DES MOINES BRICK MANUFACTURING CO.

ABRASION AND IMPACT—RATTLER TEST.

General pavers, end cut common, from brick for paving Cedar Rapids, Iowa, season of 1896.

E. B. BOYNTON, C. E.

MARKS.	Revolutions per minute.	Total revolutions	WEIGHT—LBS. Original.	Final.	Loss.	Loss, per cent.	CONDITION AFTER TEST.
C. 4 VI.	33	800	6.25	5.76	.49	7.84	Even wear.
I. 3 IX.	33	800	6.32	5.76	.56	8.86	Chipped corners.
B.-S.-1.	30	800	6.22	5.76	.46	6.40	Some chipping, were generally even.
L	33	800	5.95	5.43	.52	8.74	Chip off corner.
1-7-X ..	32	800	6 37	5.85	.52	6.16	Wear even.
Z.... ..	32	800	6.50	5.96	.54	8.31	Chip off one corner.
Av'g.	....	......	....	....	..	8.05	

TABLE IV.

DES MOINES BRICK MANUFACTURING CO.

ABSORPTION TEST.

General pavers, end cut common, from brick for paving Union station grounds, Cedar Rapids, Iowa, in 1896, made in 1895.

E. P. BOYNTON, C. E.

MARKS.	WEIGHT IN POUNDS.		Gain.	Per cent of gain
	Dry.	After immersion		
D-6-II	4.95	4.97	.040	.80
D-6-V	4.36	4.385	025	57
D-6-T	4.80	4.82	020	.41
D 6-L	5,09	5.11	020	.39
D-6-IX	4.87	4.90	.030	.61
D-6-X	4.82	4.845	.025	.52
Average	......	....	...	.56

TABLE V.

DES MOINES BRICK MANUFACTURING CO.

TRANSVERSE RUPTURE TEST.

Broken in registering hydraulic press. Modules of rupture $= M = \frac{3\,l\,w}{2\,b\,h^2}$ in which $l =$ length between supports, $= 6$ inches, $b =$ breadth and $h =$ depth of brick, $w =$ breaking load

General pavers, end cut common, from brick for paving Union station grounds, Cedar Rapids, Iowa, in 1896, made in 1895

E. P. BOYNTON, C. E.

MARKS.	b.	h	w	m.	REMARKS
D-S-I	4.05	2.40	7,000	2,695	Medium dark reddish.
II	4.02	2.38	6,200	2,453	Brown color, with many white and red pebbles
H	4.00	2.35	6,900	2,810	Few lamination cracks
Z	4.10	2.32	5,600	2,291	Break on two or three edges.
V	4.11	2.35	7,200	2,856	With square even fracture.
Average				2,621	

The figures given in tables III, IV and V are obtained from tests made on the general paving brick manufactured by the company. A combination of the results according to the general formula, $V = (20 - R)\,6 + (8 - A) + \frac{T}{110}$, gives a rating of 101.95, a most satisfactory showing. The ratings given in

table I, are somewhat lower, though still quite satisfactory. This is explained by the fact that the latter figures were in part based upon special brick manufactured from each clay. The difference demonstrates that in practice the clays are so combined as to compensate individual defects. The high rank is largely a result of the toughness. This indicates very careful burning.

Flint Brick Co.—This company has an extensive plant located in Oak Park upon the Des Moines river. They ship over the Flint Valley line of the street railway and are also within easy hauling distance of all parts of the city. The property includes a coal mine and a brick plant, both having been opened in 1893. The details of the section exposed in the pit are given below.

		FEET.	INCHES.
12.	Clay (Pleistocene)	3	
11.	Shale, varicolored, the lower portion of the nature of a fire clay	8	
10.	Shale, buff to gray, gritty	6	
9.	Limestone, impure		6
8.	Shale, red and bluish gray; laminated	6	
7.	Shale, brick-red in color, clean unctuous	4	
6.	Shale, light gray		4
5.	Shale, crumbly, gray	1	6
4.	Shale, "blue"	28	
3.	Shale, bituminous		8
2.	Coal, soft, "pockety"	1	
1.	Fire clay	1	

Above number 4, the entire section is fully exposed. The lower numbers were encountered in sinking the shaft. The coal is the seam exposed along the river and already mentioned. Excepting numbers 9 and 12 the entire section of clay is suitable for use.

Analyses of the clays are given in table VI, the analyses being made by Professor C. O. Bates, and published through the courtesy of the company. The samples are taken from the top down. As these samples were taken at a different time from that at which the section just given was made they cannot be exactly correlated with the members noted.

TABLE VI.

CHEMICAL ANALYSES FLINT VALLEY CLAYS.—C. O. BATES, *Chemist.*

	1.	2.	3.	4.	5.	6.	7.
Silica, total, $Si\ O_2$	70.23	69.89	58.92	50.38	62.70	64.31	64.03
Alumina, $Al_2\ O_3$	15.68	17.68	21.45	27.25	21.32	17.64	20.73
Water, combined, $H_2\ O$	1.82	1 97	4.13	3.62	4.90	5.47	3.50
Clay and sand	87.73	89.54	84.50	81 25	88.92	87.42	88.26
Oxide of Iron, $Fe_2\ O_3$	7.44	5.68	8.40	11.54	5.88	7.68	6.72
Lime, Ca O	.47	1.05	.98	.96	.16	1.12	.36
Magnesia, Mg O	1 50	1.68	2.90	2.93	1.77	2.40	2.57
Total alkalies	1.26	1.15	2.49	1.65	1.15	1 15	1.30
Fluxes	10.67	9.52	14.77	17.08	8.96	12.35	10.95
Water, free, $H_2\ O$	1.50	.85	.57	1.45	2.12	.42	.42
Total	99.90	99.91	99.84	99.78	100.00	99.99	99.63
O. in acid to O. in base	3.87	3.18	2.15	1.48	2.59	2.81	2.57
Ox. in Alk. to O. in fluxes	3.29	2 76	2 29	2.43	3.62	2.16	2.84

The clays are carried to a dry-pan of the Eagle Iron works make. After being crushed the material is elevated to a screen from which the coarse material is returned to the dry-pan and the fine is sent to a Penfield pug-mill. From this machine it goes to a No. 20 Penfield brick machine with a revolving cut-off. The brick are dried in an iron-clad dryer, the temperature ranging from 160° at one end to 220° at the other. Little or no checking occurs unless too much of No. 12 is used. The brick are burned in Eudaly kilns of 225,000 capacity. The main output of the plant is paving brick, but hard burned building brick, both rough and smooth, in dark red and buff colors, are also marketed.

In the Boynton tests the pavers from this plant, taken from stock, gave a per cent of absorption of .93 as an average of ten tests, the results ranging from .53 to 1.22. The modulus of rupture was found to be 2,740 as a result of three tests. The rattler test gave 12.49 (actual and rational) as a result of ten tests ranging from 9.57 to 14.59. These figures give the brick a rating of 82.25 according to the formula.

Iowa Brick Co.—The works of this company are located in the northwestern portion of the city across the river from the

Flint brick works. The plant, which is quite extensive, was opened in 1893. The shale is mined by blasting and digging and hoisted by tail-rope to the receiving room, where it is dumped into two Frey-Sheckler dry-pans. From the latter it is elevated and run through a revolving screen (4 x 9 feet), the tailings returning to the dry-pans. The clay goes from the screen to a Frey-Sheckler pug-mill, being fed into the latter through a Cook automatic mixer. This is an ingenious machine in which the amount of clay passing through the

FIG. 66. Iowa brick works

hopper and spread upon an endless belt regulates the amount of water turned into the pug-mill. The mixer can be set so as to furnish a certain percentage of water and beyond that preliminary gauging requires no attention. It does away with the necessity for a man at the pug-mill and has many important advantages in addition. From the pug-mill the clay passes to a Cunningham brick machine. From the latter the brick go the repress, of which they are three of Bonnott make. At the repress they are loaded upon iron cars which run through the dryer. The latter has fifteen tracks,

each holding twelve cars, giving a total capacity of 75,000 brick. It is heated by live steam and ordinarily 65,000 brick are run through in twenty-four hours. At the discharging end of the dry-house is a transfer track so that the cars may be run into the kilns. Of the latter there are seven large ones of Dewhirst pattern, and one bee hive. The plant includes a 250 horse power Bass engine and four 80 horse power boilers of the same make. This company makes both building and paving brick and in the past three years has put out about 26,000,000 brick. In making the pavers the whole of the section is used. The clays vary greatly in appearance and character as is shown by the following section and analyses taken from the report made to the company by Mr. E. P. Boynton.

		FEET.
1-1.	Shale, variegated, reddish brown, mahogany reds, yellowish, bluish drab, dark gray, almost black; the colors mottled parallel to bed	6
1-2.	Sandy, light yellowish white, solid color	6
1-3.	Slightly sandy at top to clear shale below, pale blue streaked with chocolate brown, to chocolate brown	5
1-4.	Shale, clear chocolate brown	4
1-5.	Shale, granular, dark solid drab with reddish purple nodules	3
1-6.	Shale, bluish drab	6
1-6½.	Same as No 6, exposed at western end of cut, weathered	
1-7.	Shale; streaks of brownish drab and greenish, to chocolate brown. Stratification well defined	6
1-8.	Clear dark drab, with olive green tinge	2

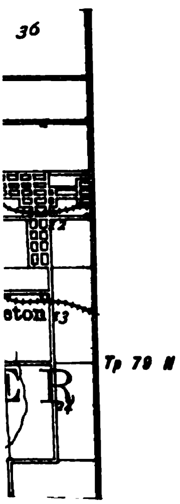


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TABLE VII.

CHEMICAL ANALYSES IOWA BRICK CO. CLAYS—C. O. BATES, *Chemist.*

	1-1	1-2	1-3	1-4	1-5	1-6	1-6½	1-7	1-8
Silica, total, $Si\ O_2$	55.98	81.79	68.50	52.88	66.73	64.60	64.82	57.25	53.05
Alumina, $Al_2\ O_3$	25.65	10.25	18.45	24.27	20.28	20.25	21.00	22.50	25.92
Water, combined, $H_2\ O$	3.73	1.27	2.82	3.28	4.92	3.74	3.10	3.62	4.40
Clay and sand	85.36	93.31	89.77	80.43	91.93	88.59	88.92	83.37	83.37
Oxide of Iron, Fe_2O_3	5.88	3.24	5.28	11.28	3.24	6.72	5.76	7.92	8.76
Lime, $Ca\ O$	.74	.52	1.19	.52	.70	1.20	.42	.90	1.00
Magnesia, $Mg\ O$	1.88	.57	1.42	2.03	.90	1.02	2.48	2.28	2.73
Total alkalies	1.95	1.75	1.27	1.92	1.46	1.33	2.11	1.41	1.29
Fluxes	10.45	6.08	9.16	15.75	6.30	10.27	10.77	12.51	13.78
Water, free, $H_2\ O$	3.72	.58	.88	3.46	1.70	1.14	.33	3.88	2.70
Total	99 53	99.97	99.81	99.64	99.93	100.00	100.02	99.76	99.85
O in acid to O in base	1.95	6.61	3.17	1.73	3 11	2.12	2.61	2.10	1 77
O in Al. to O in fluxes	3.81	2.78	3.13	2.39	5.14	3.12	2.99	2.72	2.84

The properties of the individual clay beds of this section may be inferred from the analyses as also from the following physical tests (see table VIII). These tests were made upon brick from the separate clays, the numbers corresponding in the two tables and the section. In addition it will be noticed that averages are given for brick made from the combined clays, end cut and side cut, both repressed and common. The brick put on the market are represented by these later tests.

TABLE VIII.

TABLE OF AVERAGES AND COMPARATIVE RATINGS—IOWA BRICK COMPANY.

E. P. BOYNTON, C. E.

MARK.	METHOD OF MANUFACTURE.	ABRASION AND IMPACT, RATTLER TEST. AVERAGES. PER CENT OF LOSS			Porosity, absorption. Per cent of gain.	TRANSVERSE STRENGTH, RUPTURE TEST. MODULUS OF RUPTURE.			Comparative rating by formula.
		Actual.	Rational	Average of 3 and 4.		Actual.	Rational.	Average of 7 and 8	
1	2	3	4	5	6	7	8	9	10
1-1	End cut common	16.53	14.68	15.60	.82	2,812	2,812	2,812	64 78
1-2	End cut common	15.01	14.07	14.54	5.74	1,929	2,176	2,052	44.45
1-3	End cut common	17.01	13.88	15.44	1.39	2,765	3.203	2,984	69.93
1-4	End cut common	17.29	15.93	16.61	.54	3,086	3,086	3,086	62 24
1-5	End cut common	22.12	20 53	21.82	4.98	2,921	2,921	2,921	11 72
1-6	End cut common	14.16	13.81	13.96	2.62	2,300	2,450	2,375	63.24
1-7	End cut common	14.28	14.28	14.28	.30	3.174	3,174	3,174	77.98
1-8	End cut common	28.00	25.00	26.50	.73	2,101	2,318	2,210	15.82
1-S	Side cut repress	14.80	13.63	14.22	.96	3,348	3,714	3,531	77.28
1-S	End cut common	16.80	15.65	16.23	.86	2,193	2,193	2,193	54.21
1-S C.....	Side cut repress	12.23	11 81	12.02	.55	3,348	3,714	3,531	92 12
1-E C	End cut common	12.28	11.45	11.87	.80	2,193	2,193	2,193	80.61

The company also manufactures terra cotta, using for this purpose carefully selected clays. In making terra cotta the clay is run through the dry-pan and pug-mill as usual and then spread upon the floor and covered with a cloth to keep moist. The pieces are moulded in plaster moulds and carefully dried. The ware is burned in a muffled kiln, so as to be protected from the fire, and requires seventy to seventy-five hours firing. Red and dark purple cornice pieces have so far been the principal output.

Capitol City Brick and Tile Works.—This plant is located on on the south side near the intersection of the Keokuk & Western and the Chicago Great Western railways. A section of the pit has already been given. At the time Mr. Boynton visited the works the exposure measured about fifty feet. His section from the top down is as follows:

		FEET.
C-0.	Clear, medium light drab with slight seams of rust, mastic, very slightly gritty	7
C-1.	Shale, mottled and streaked, maroon to sea green, greenish and purplish brown, rust in seams	4½
C-2.	Shale, medium dark bluish drab, clean	7
C-3.	Bastard fire clay, mottled purplish blue, dark grey, slight rust in seams	4
C-4.	Shale, soapy, but containing some grit, clear greenish drab	15
C-5.	Shale, very dark greenish grey with slight seams of rust	1½
C-6.	Shale, clear blue sandy	10

Samples taken from each layer were analyzed (see table IX) and brick made from the individual layers were tested with results as shown in table X. The numbers designating the individual layers of the section correspond with those of the analyses and tests.

TABLE IX.

CHEMICAL ANALYSES OF CLAYS—CAPITAL CITY BRICK & PIPE CO.

C. O. BATES, *Chemist.*

	C-0.	C-1.	C-2.	C-3.	C-4.	C-5.	C-6.
Silica, total, $Si\ O_2$	55.25	53.08	61.18	68.60	65.62	51.35	58.42
Alumina, $Al_2\ O_3$	25.60	24.93	21.69	18.93	16.83	27.38	20.04
Water, combined, $H_2\ O$	5.07	5.73	5.01	2.80	4.10	5.42	5.40
Clay and sand	85.92	83.74	87.88	90.33	86.55	84.15	83.86
Oxide of Iron, $Fe_2\ O_3$	5.52	9.00	5.88	6.12	8.64	6.60	7.80
Lime, $Ca\ O$	1.75	.94	.51	.25	.42	1.45	1.60
Magnesia, $Mg\ O$	1.49	1.84	1.92	.68	2.00	2.62	2.67
Total alkalies	1.79	1.19	1.96	.74	1.66	2.34	1.56
Fluxes	10.55	12.97	10.27	7.79	12.72	13.01	13.71
Water, free, $H_2\ O$	3.27	3.29	1.27	1.80	.60	2.81	2.39
Total	99.74	100.00	99.42	99.92	99.87	99.97	99.96
O in acid to O in base	1.93	1.78	2.43	3.23	2.95	1.62	2.27
O in alumina to O in fluxes	3.82	2.95	3.28	3.80	2.04	3.25	2.23

In making the brick the material is hoisted to a Frey-Sheckler dry-pan with a tailings crusher of the same make, and is moulded on a No. 10 Penfield machine. There are two large brick-walled tunnel dry-houses of nine tracks each and

with a total capacity of 60,000 brick. The temperature used is about 200° F. The kilns include three Eudaly, one round and two rectangular, seven round down-drafts and one open kiln. The burning, including water-smoking, requires ten days. Paving brick of excellent quality is the main output, though large quantities of building brick are also marketed.

TABLE X.

PAVING BRICK TESTS—CAPITAL CITY BRICK AND PIPE CO.

E. P. BOYNTON, C. E.

MARK.	METHOD OF MANUFACTURE.	ABRASION AND IMPACT, RATTLER TEST. AVERAGES. PER CENT OF LOSS. Actual	Rational.	Average of 3 and 4	Porosity, Absorption test. Per cent of gain	TRANSVERSE STRENGTH, RUPTURE TEST. MODULUS OF RUPTURE. Actual.	Rational.	Average of 7 and 8	Comparative rating by formula.
1	2	3	4	5	6	7	8	9	10
C-1.......	End cut common	16.91	16.30	16.64	.97	3,375	3,544	3,460	63.74
C-2......	End cut common	18.73	18.73	18.73	1.03	2,858	2,858	2,858	45.48
C-3.......	End cut common	12.91	17.17	15.04	8.60	1,714	1,714	1,714	28.76
C-4.......	End cut common	18.60	16.61	17.60	.67	3,930	3,930	3,930	63.45
C-5......	End cut common	69.49	69.49	69.49	1.38	1,998	1,998	1,998	......
C-6.......	End cut common	12.49	12.49	12.49	.60	3,429	3,429	3,429	89.82
C-G. P...	End cut common	17.78	17.61	17.70	.54	3,896	4,080	3,988	62.89

The brick marked C. G. P. represented the general pavers. They did not, however, represent the general stock of the company since they were in part of 1895 manufacture, and at the time they were selected the yard was entirely stripped. It is interesting to note that the bastard fire clay, C-3, produced a brick of high absorption and low transverse strength, though of considerable toughness. The best brick are made from the lower clay, C-6, and at this plant, as at the others, the more recent brick are much better than those first turned out. It is also interesting to note in connection with the

analyses, the variations in color and other physical properties. These are summarized by Mr. Boynton as follows:

C-1. All of good form; medium dark buff color with purplish tinge. All show slight kiln marks. No ring.

C-2. All good forms, good corners; light reddish buff color; appear glassy; brittle; sharp clear ring.

C-3. Good form; very light pale yellow with pinkish tinge; blotches of lemon yellow on ends; dull spongy appearances and no ring; looks like fire brick.

C-4. Good form; light buff color with purplish tinge; good ring.

C-5. Good form; buff color with reddish tinges; poor ring; glassy, brittle appearances.

C-6. Good form, but slightly kiln marked; medium dark buff with purplish tinge; good ring.

The effect of the lime and magnesia in holding down the color is excellently illustrated by the brick. The clays carry from 5.52 to 9 per cent of iron (Fe_2O_3) enough to give a good red color under ordinary conditions, and yet they are predominantly buff. Variation in color seems to be due in but slight part to the burning, since it is nearly proportional to the change in composition. This is suggested by the following comparison between the color and the ratio existing between the total iron and the sum of the lime and magnesia.

		RATIO.
C-1.	Buff, pinkish tinge	1:.308
C-2.	Light reddish buff	1: 413
C-3.	Pale yellow, with pinkish tinge	1:.157
C-4	Buff, pinkish tinge	1:.280
C-5.	Buff, reddish tinge	1:.516
C-6.	Dark buff, purplish tinge	1:.574

BUILDING BRICK.

As has already been suggested the loess and the alluvium are the materials chiefly used for manufacturing building brick. The clays and shales of the coal measures have not been much used except at the paving brick works. Where the shales are used for building brick they are usually mixed with loess.

For building brick, clays of great variety in composition and texture may be used. The sandy alluvium and the dense shales each have their use. The qualities to be desired in building brick are (1) low cost, (2) good shape, (3) suitable color, and (4) moderate strength. For "common" brick, a fair strength being secured, the matter of cost becomes most important. For this reason hand-made alluvial brick and rejects from other grades make up the bulk of the material supplying the trade. "Stock" brick require more care as to shape, and a careful sorting so as to secure uniformity in color. "Roman brick" require very careful manipulation in order that the desired shape and color may be perfectly maintained. Enameled brick are made by treating the better class of stock brick.

In those grades where smooth surfaces and sharp edges are required the results may be obtained by using either the repress or the dry-press. If a change in color be desired it can often be brought about by a change in treatment. The red color of most brick is due to the presence of 3 to 5 per cent of iron and the absence of lime and magnesia. In the presence of the latter double silicates of lime and iron are formed and a cream or buff brick results. According to Wheeler the red color will sadden if 5 per cent of lime and magnesia be present, at 10 per cent the brick has a yellowish cast and at 15 per cent it becomes a deep to pale cream. The temperature of burning also influences the color. A brick which is a dull salmon color when burned at red heat (1,000° to 1,200° F.) becomes a deep salmon at slightly higher temperatures (1,300° to 1,400° F.), a light red at bright red heat (1,500° to 1,600° F.) and deep red at still higher heat (1,800° to 1,900° F.). At bright cherry heat (2,000° to 2,200° F.) it becomes a very dark red and at slightly higher heat (2,300° F.) it usually fuses and turns black.

If the brick be very slowly heated in the water-smoking stage the color is deeper and richer from the more thorough oxidation of the iron. When very dark brick are desired they may be secured by burning with a smoky flame.

By proper manipulation a wide range of color may be obtained, as is indicated by the results of the tests at the Capital City plant. A still wider range would have been obtained if the conditions of burning had been purposely varied. So far only common and stock brick have been regularly placed on the market from Des Moines. At present the main output is red brick, with a few buffs. Smooth faced brick are generally preferred, but recently there has been a growing demand for rock faced. The paving brick works supply an important portion of the building trade as the brick which are not good enough for use as pavers are excellent for building purposes. A considerable portion of these are sold for rock-face work.

Newman Brothers. This firm formerly operated a small plant in East Des Moines for the manufacture of building brick; recently, however they have opened more extensive works on the Wabash railway near Hastie. The locality has already been noted in connection with the mines of the Iowa Fuel Co. The clay consists of coal measure shale and is crushed by means of a Bonnot dry-pan, made at Dayton, Ohio. From the dry-pan it goes into a pug-mill of the same make. After being mixed and tempered it is moulded as a stiff mud upon Bonnot end-cut machines. The green brick are dried by live steam in twenty-four to thirty-six hours in an eight track dry-house of 40,000 capacity. The clay drys with no checking. In burning, two cased kilns of 150,000 capacity each, and one round down-draft of 60,000 capacity are used. The brick are water-smoked in two or three, and usually burn in seven or eight, days; occasionally they require nine or ten days burning. So far few pavers have been made, the trade being mainly in building brick. The two styles of brick are made from the same clay, but the pavers are burned harder.

Merrill Brick Works.—This plant is located on the Keokuk & Western railway, some distance south of the Capital City plant. The material is taken from the foot of the Raccoon river bluffs and consists of coal measures capped by loess. The following section is shown in the pit:

		FEET.
7.	Soil and loess	3
6.	Slate, bituminous	$\frac{5}{6}$
5.	Shale, blue to gray and buff	4
4.	Shale, red to brown, more or less variegated, containing ironstone concretions	20
3.	Shale, blue to gray	6
2.	Coal	$1\frac{1}{2}$
1.	Shale, light gray	7

All of the material in the pit except the coal and bituminous shale is used in the brick. Numbers 1 and 3 are of particularly good quality. In treatment the clay passes through a Des Moines Supply Co. dry-pan, a Wallace pug-mill and a Great Wonder brick machine. From the machine the brick go to a tunnel dryer heated by exhaust steam in the day time and live steam at night. Three Pike kilns and one open kiln are used in burning, the process requiring ten days, including four days of water-smoking. At present building brick only are made, though it is the intention of the company to arrange for the manufacture of pavers, repress and finish brick. The material now turned out is strong, dense and of good color.

Dale-Goodwin Pressed Brick Co.—The works of this company are located upon the Winterset branch of the Chicago, Rock Island & Pacific railway, southeast of Des Moines (Tp. 78 N., R. XXIV W., Sec. 24). The material used is the loess. A descriptive section has already been given. The surface material is plowed and allowed to become almost dry before it is carted to one of the large sheds under which it is stored. From the sheds the clay is passed through a Ross pulverizer, and after being screened it goes into the bags of the machine. The latter is a Ross-Keller No. 2, six-mould, with a pressure of 30,000 pounds per square inch. The green brick are wheeled directly to the kiln, four up-drafts of Repell pattern of 240,000 capacity each. The brick burn in seven days with coal, after eight days water-smoking with wood. A good cherry red color is obtained and the brick meet with ready sale. This is the only plant in the city using the dry-press

process, and the success attained is quite encouraging in view of the large amount of loess available. The plant was erected in 1893, and has not been operated so continuously as would have been possible under normal business conditions. As a result the product is not so uniform in quality as has been obtained from the loess at some other points, but it has been abundantly proven that brick of the best quality can be made.

Local Brickyards.—There are a large number of small plants scattered throughout the city which make brick in the main by the hand process. They are not always permanent, but many have been operated for several years. Most of them are noted below.

The Minear Brothers brickyard, southeast corner of Twenty-first and Maury streets, was started in 1889 and has since continued in operation. Slap brick are made from clay taken from a seven-foot bank. Soily material at the top to a depth of one foot is removed and the underlying alluvium is utilized. At a depth of twelve feet quicksand and water are reached; this is near the water level of the Des Moines, which flows less than a half mile away.

Louis Shackelford has a brickyard at the northwest corner of Fair avenue and West street. A Chief machine operated by horse-power was put in in 1893. Prior to this time slap brick were made. The moulded product is dried in open air and burned in either clamp or cased kilns. The raw material is taken to a depth of three and one-half feet from the flood-plain of the Des Moines. In the upper part it contains considerable vegetable material. Below it is brown in color and more clay-like. The clay grades into quicksand and gravel. The brick from here have been used in various buildings, including the National Starch Works, the Windsor Packing House and the Painter block.

Lincoln Shackelford operates a small brickyard just east of Victoria street, between West street and the Wabash railroad. Two pug-mills with one gang of men are employed, the product being common slap brick made from alluvial material

taken to a depth of nearly three feet. The brick are burned in down-draft kiln, with a capacity for 65,000 brick. The product is of very good grade, and has been used in the construction of some of the principal business houses in Des Moines, including the Turner block.

T. J. Fredregill is the owner and operator of a brickyard just to the northwest of the Lincoln Shackelford plant. The force consists of but one squad of men. Alluvium from the Des Moines valley is used to a depth of three feet. The brick are dried on the yard and burned in cased kilns with wood as fuel. They have a good red color and are quite firm for a hand-made article.

J. M. Fredregill makes slap brick on a yard north of the Wabash track and east of the York addition. Work has been carried on at the point several seasons. The clay is similar to that used at the other points in this vicinity, but here it is taken to a depth of from three to four feet, utilizing the surface loam. Under the clay gravel is struck.

J. Bailey now operates the once abandoned Cook Brothers brickyard, located east of Twentieth street on the north side of the Chicago, Rock Island & Pacific railroad. Here again hand made brick is the product, the material being the alluvial clay which is, including the soil portion, about four feet thick, and below which is gravel of the Wisconsin gravel train. The yard is supplied with two stationary kilns with a total capacity of 250,000 brick. The product is used principally for interior walls and sidewalks.

The J. D. Hill brickyard is just east of Twentieth and north of Maury streets. This plant is quite extensive. The brick are made from alluvial soil and subsoil taken to a depth of seven feet. The Old Reliable soft-mud horse power machine is used and about 22,000 brick is the daily capacity. Two clamp kilns holding 275,000 brick are used in burning.

Louis Youngerman is the owner of a brickyard which lies just north of the western end of Dean Lane. A triple force of men are employed. Ordinary silty clay of the Des Moines

"bottoms" is mined four feet deep. This affords a very fair common brick. Two clamp kilns are used in burning. These have a capacity of 125,000 each.

N. Haskins has been making brick in Sevastopol for about ten years. The brick are now made on two Old Reliable soft-mud machines, each having a capacity of 7,500 daily. Five clamp kilns and one Haskin patent are used in burning. The raw material is loess from the hillside by the yard. The upper six feet of the deposit is yellowish to brown, slightly ocherous, and at the bottom it grades into a grayish sandy variety. The burned product has a good rather bright red color and is quite substantial in quality.

South of the street from the N. Haskins yard and just north of the Van Ginkel coal mine is situated the brickyard operated by G. Van Ginkel. Loess is taken from a bank two to eight feet deep near the plant and moulded by two Tiffin Old Reliable and one Chief soft-mud machine. The clay is of good quality and suitable for the manufacture of even a much higher grade of brick, although those manufactured are of very good quality for a common brick.

Tippey & Decker operate a hand yard two miles beyond the eastern limits of Des Moines, about half a mile from the Wabash tracks. This brickyard was started in 1893 and has since been running on a small scale. Alluvial material is utilized.

The Frank Collins brickyard is situated a short distance north of the Des Moines river to the east of Sixth avenue. Work was commenced in the spring of 1893, using the soil and under clay of the flood plain. The product is hand made and the annual output is small.

In the northwestern part of Des Moines, north of Franklin avenue and west of Twenty-third street, G. L. Winburn operates the brickyard formerly owned by E. S. Close. Upland soil is used to a depth of two feet; below this the moulded material is too liable to crack when becoming dry, as there are no sheds to protect the slap brick. The brick have good color and do very well for basement and interior walls.

L. J. Williams has been making slap brick about one-fourth of a mile north of St. Joe street and west of Twentieth street for several seasons. The material used is upland soil. It is taken to a depth of eighteen inches. The clay is prepared in ordinary pug-mills and the moulded articles dried on the yard.

On Twentieth street and Hickman avenue is a brickyard now owned and operated by Kuntz & Hall. It has been operated for more than fifteen years. The surface eighteen inches are stripped off and the under sixteen feet are utilized by being put through an Ideal machine of the Decatur Leader Manufacturing Co., which machine was put in at the beginning of the season of 1893. This plant is well arranged so far as methods and location with respect to the raw material and kilns are concerned. It is the only one in Des Moines making brick of loess alone on a stiff-mud machine, and the product is of good strength and appearance. Three stationary kilns are employed.

SEWER PIPE AND POTTERY.

Aside from brick the clays found near the city have, as yet, been but little used. There is, however, one extensive sewer pipe plant and a few small potteries.

Iowa Pipe and Tile Co.—This is the largest factory in the state devoting attention to the manufacture of sewer pipe and other articles which are made by the same processes. It is situated on the east bank of the Des Moines river about half a mile north of Locust street. The plant has been in operation for some years and has just been rebuilt, having been burned within the year. The buildings include the main structure, 167 by 90 feet, three stories high; a wing, 90 by 37 feet, two stories high, and a small office building. The clay is brought from the bank to a Vaughn dry-pan from which it passes into a screen; from the screen the mass is conveyed to a bin, from which it is transported into two Frost wet-pans, from which it is taken to press feeders, and then into the two Vaughn presses for sewer pipe, or into the Brewer press for

drain tile. The raw material is as conveniently located as could be desired, the plant being situated immediately between the pit and the river. The section has already been given.

Of the sandy material at the top only a part can be used, as it stands only moderately high heat. For sewer pipe the best grades are selected and various combinations are taken for the other products. The ten feet of shale at the base of the section is of very fine quality. It is the extension of the layer which is mined just across the river and used at the Updike and at the Weeks potteries. A few impurities are shown in the burnt ware and if these were removed by washing the material could probably be used for white glazed and unglazed ware, for glass pots, crucibles and many other products.

The factory is well equipped and well managed. The sewer pipe made are of excellent quality, and fully attest the fact that the local clays are able to not only supply local demands but to make their way into the general market.

Eagle Pottery Works.—This is an old established pottery, located on Elm and South Second streets. Common coarse stoneware, glazed and unglazed, has been manufactured for a number of years, though the plant is not at present in operation. The clay is from the coal measures. It is mined from the J. Fox slope, opposite the plant of the Iowa Pipe & Tile Co. The best part of the vein is seven feet in thickness. It is quite hard when first mined, and for this reason the material is allowed to weather for a year or more. It becomes thoroughly broken up and disintegrated and is more readily worked. After a thorough grinding in a wet-pan or chaser of the Webster, Camp & Lane manufacture, it is prepared by hand for the wheel. The wet ware is placed in steam-heated apartments and dried. It is then put in a rectangular downdraft kiln and burned. It stands much firing and readily takes a very fine glaze, for which purpose Albany slip is used. The style of ware is varied, and all sizes of jars, from the quart to the twenty gallon are made. There are minute

impurities in the clay and the unglazed products disclose their presence. Washing would no doubt remove them, but the glaze conceals the impurities and makes the extra expense unnecessary.

Weeks Pottery Works.—This plant was started a few years ago on South Sixth street near Raccoon street. It is quite an extensive factory, with brick buildings, two rectangular down-draft kilns, a wet-pan or clay chaser, with dry-rooms, wheels and other necessary appliances. The factory was started with the intention of making pottery especially, but early in 1893 this plan was abandoned, and chimney tops were manufactured. The expense of purchasing the raw material made the factory only an indifferent success, and it is not now operated. The clay itself is of good character. It is the same as used at the Eagle works, and is taken from above the milldam, where it is mined by means of a slope. The material is a fine arenaceous clay. It stands much firing, does not "cripple," and readily takes a bright glaze.

BRICKYARDS OUTSIDE OF DES MOINES.

Altoona.—The E. E. Haines brickyard and tile factory is situated on the north side of the Chicago, Rock Island & Pacific tracks, a short distance west of the station at Altoona. The surface deposit is a sloughy clay, which has accumulated in one of the saucer depressions of the Wisconsin drift. It is three feet thick, and below it there is a yellow bowlder clay bearing numerous lime concretions. The slough clay was at one time mixed with coal measure shale in the ratio of one to two. This latter material was mined from the Haines coal shaft near by, at a depth of 215 feet.

The so-called fire clay underlying the vein was taken out by the miners from the entries and runs. Since the coal seam was undulatory and not very thick, the removal of the under clay was necessary to get work room. This fire clay is a grayish to blue shale, white when first mined and very plastic. It contains numerous pyrite concretions, which, in the long

exposed heap of clay used in the factory, have been changed into the hydrous oxide. The raw material is run through a Penfield corrugated roller crusher and disintegrator, then into a No. 7 Penfield plunger. The wet product is placed in sheds and allowed to dry. After drying the brick are burned in two round down-draft kilns. The burning consumes from three to three and one-half days; water-smoking about a third of the time. The brick and tile, the latter three to eight inches in diameter, are quite strong, and, except for occasional dark spots due to the presence of pyrites, the general appearance and color is excellent.

Polk City.—The C. Billington brickyard is in the southwest corner of section 35, Madison township, nearly two miles northwest of Polk City. Work was inaugurated at this point about fifteen years ago. The yard is on the upland, and the material used is from one to ten feet thick, being entirely superficial. It is a bleached drift clay, and lower down has the jointed character typical for the bowlder clays. While drying the brick are placed on racks in roofed sheds; they are burned in temporary kilns in about eleven days. For a hand-made article the product is quite good. Its use is almost entirely local.

Polk City Tile Works.—This factory, operated by Harmon & Hug, is near the station, but the raw material, which is used principally for drain tile from three to twelve inches in diameter, is hauled from near the Des Moines river, a little more than a mile southwestward. This clay is of coal measure age and the greater portion of it is of very good quality. It is mixed with drift clay taken from near the plant. The bottom bed shown in the pit from which the coal measure clay is taken, is a more or less variegated shale. The lower third is a dark gray variety with some iron stainings, and containing certain lenses of nearly pure red hematite, which are removed by the disintegrator. The upper portion is brick red in color and is of excellent quality. Above this is a clean gray shale which is separated from the purple shale just below the drift

by a thin limestone ledge. The upper shale is three feet thick; the color is gray to red and purple. The bowlder clay is of little value since it either bears many concretions of lime or is too arenaceous for use.

The different beds of the section are mixed together. After being run through the Brewer crusher and disintegrator the mixture is put through a Continental brick and tile machine, Tiffany patent. This machine has been in service since the erection of the plant in 1882. The product is dried on pallets in closed sheds into which are run exhaust steam pipes. Two common down-draft kilns are used in burning, and four days are required for the process, the water being driven off in a single day. Building brick of a good cherry red color have been produced from the material used in making tile, and some fire brick for use in the kilns have been manufactured of the white shale clay which is just below the base of the section described. A clay upon which rests the coal vein at the Polk City mine near the tile plant has also been used for fire brick. Both afford a very fair grade of brick.

Campbell.—Thomas & Son have a small drain tile and brick factory just north of Campbell station. The product is largely drain tile in sizes from 3's to 6's. A few brick are also made some seasons. The machinery is a horse power plunger, the Hocker, and the product is dried in closed sheds to prevent its cracking. The material for the tile is taken from a twelve foot bank of yellow bowlder clay at the foot of the slope northwest across the branch. At the northwest corner of the cut a fine quality of argillaceous coal measure shale is exposed and by digging, a heavy deposit of this shale, which will do well for brick, tile and other products, could probably be found. Thus far scarcely anything but the bowlder clay has been utilized. The process of putting salt in the burning kiln, is practiced at this yard. It is claimed that by the introduction of five or six gallons of salt in each of the round down-draft kilns a harder and redder tile is secured.

Bondurant Tile Works.—This plant is owned and operated by Mr. A. M. Austin and is located near the Chicago Great Western, just west of town. It was opened in 1893, but was not operated during the past season. The clay used is a slough clay and is mined to a depth of five feet. It is moulded on a Penfield machine, dried under a shed and burned in a down-draft kiln.

Soils.

Among its sources of wealth Polk county has none of greater importance than its soil. The annual value of the farming products of the county amounts to more than the value of all the other products combined. The county is essentially a farming county. The mining interests, as compared with the agricultural interests, are small.

The soils of the county are drift soils. Throughout the northern portion, the area mapped as Wisconsin drift, the till itself comes to the surface, being only occasionally covered to any considerable thickness by pebbleless material. The drift soil is black, and is usually not so open as the loess or alluvium. It suffers from the disadvantage of imperfect drainage, and considerable areas are slough-covered, though the percentage of slough land is not so great as further back on the Wisconsin. The area covered by modified drift, in part imperfectly drained, is usually more available. The material has been better sorted, is more sandy, and, except where the surface is too gravelly, affords an excellent soil. The alluvium covers a not inconsiderable portion of the county and is of well known value. The bottom lands of the rivers are particularly well adapted to the culture of corn. They are rarely overflowed. Owing to the fact that in many cases the alluvium forms merely a top dressing over the gravel trains or other drift with which the old valleys were partially filled, the bottoms usually have free underground drainage.

Over the southern portion of the county the surface material is the loess. This rests upon the Kansan drift, the upper surface of which is usually gravelly. The combination

affords a most excellent soil. The loess being fine and homogeneous is easily worked and has an important mechanical effect upon the water content. The material is so porous that the water instead of running over runs down into it. The even regular texture makes the distribution of the surface tension exceptionally even. As a result, any given area of loess becomes a vast reservoir, which, upon being tapped by plants, gives up its moisture in regular quantity. This is a distinct advantage, particularly in raising fruit, and the region south of Des Moines should become a great fruit region. The farm of Berryhill & Shaul is located on a loess area, and the excellent results there obtained show what may readily be done with this soil.

Gravels and Road Materials.

While the drift as a whole contains a vast amount of broken rock, definite gravel beds are not always easy to locate. As has already been suggested the deposition of gravels by the streams flowing out from an ice sheet is a function of the general attitude of the land. The gravels are only possible when there is free drainage so that the water may have sufficient velocity to carry the material long enough to sort it. These conditions obtained at the time of the Wisconsin ice invasion, and as a result we have the gravel trains leading out from the drift border. They are well defined along Camp creek, Four Mile and the Des Moines river.

In the valley of Four Mile, at Berwick, the Chicago Great Western railway takes gravel from a terrace rising twenty feet above the stream. The stripping, which is removed by scrapers, consists of two to two and a half feet of brown loam running up into black drift. Below this is twelve to fifteen feet of gravel resting on a blue to green apparently pebbleless clay. The gravel is new, fresh and hard. It is cross-bedded and interlaminated with some sand. It has a fair percentage of cobbles, but very few large stones. It shows very little ferrugination, no noticeable coloration or cementation, and

weathered rocks are relatively rare. It is known to extend along the stream for some distance, the terrace being easily followed. The gravel is mined by a steam shovel and used for ballast along the railway.

At Avon the Chicago, Rock Island & Pacific railway has gravel pits which have been worked for eighteen years. They are located upon the flood plain of the Des Moines near the station. The stripping consists of six to eight feet of alluvium, below which is twelve to fifteen feet of gravel, cross-bedded, sand streaked, and resting on fine sands. The extent of the gravel is not known, but the presence of driven wells throughout the region indicates a rather large area. It does not extend up North river, but seems to belong to the body shown in the numerous abandoned gravel pits in East Des Moines.

At Polk City the Chicago & North-Western railway has gravel pits in the valley of Big creek. The stripping consists of one and one-half to three feet of black loam, below which the gravel is about eighteen feet in thickness. It is fresh, hard and sandy, as at Avon. It forms a well marked terrace, appearing on both sides of the valley, Polk City being built upon one of the benches. The terrace may be traced down the stream to its mouth. It appears at intervals along the Des Moines valley, and is well shown near Saylorville and Highland Park, where it has recently been opened up. Gravel may be obtained from it at a number of points.

The Polk City gravel is of quite recent age, since it forms a part of a terrace made in that portion of the Des Moines river valley which is itself post-Wisconsin. Reasons have already been given for thinking that the excavation of the upper portion of the Des Moines valley was relatively rapid, and the facts in this case fit in with that assumption. The gravels mark stages in the retreat of the ice, but so far they have not in all cases been connected with definite moranic accumulations. In the valley of Camp creek the gravel train may be followed up the valley to the point where the Wisconsin drift appears, but not beyond.

While the gravel occurs in the terraces, and farther from the drift border under the alluvium, it should not be forgotten in locating gravel pits that there are terraces in the region which have had other origin, and which do not contain gravel. Neither is all the gravel in the terraces. The kames afford a supply, and there are in addition scattered patches and aggregates of irregular form, such as occur between Polk City and Crocker. Throughout the northern portion of the county these gravel patches are common. They may be looked for anywhere within the Wisconsin area as mapped.

The importance of the gravel patchs, kames and terraces arises from the excellent material which they afford for railway and road ballast. The gravel found at Highland Park has recently been used for making concrete, and the railways have for many years hauled gravel from Avon and Polk City. It is, however, in connection with the common roads that the gravel beds are destined to have their highest value. The material occurring here is mainly of hard, undecomposed pebbles. In general it is moderately coarse and much freer from sand than at many gravel pits. It has rarely been cemented at all so that it can be easily worked. All that is necessary is to shovel up the material and haul it to the roadway. In most cases the haul would be short, since the grave patches are quite widely scattered throughout the northern portion of the county.

Mine slack has been to some extent used for road improvement near Des Moines. It is good material, and can often be used to advantage. It, with river gravels, must be the main reliance of the southern portion of the county. The small total quantity of slack and its limited distribution as compared with the gravel, makes it of less general value than the gravel.

Some of the slough clays resemble in character the impure black clays which, in Wisconsin and Missouri, are burned for railway ballast and road metal. They have not yet been tested, but some, at least, would probably be suitable. Burned clay

may be very simply produced by hand process, at a cost of about 50 cents a cubic yard. A machine plant will produce it at from one-half to two-thirds of this price. It is an excellent material, and well adapted to road use.

Building Stones.

The coal measures as developed in the county do not afford any considerable quantity of good building stone. The sandstones already mentioned have been quarried a little, but are of indifferent value in comparison with the clay goods made from the same formation. At the foot of Capitol Hill are the most extensive quarries. These afford a sandstone which has been used for foundations, walls, and to some extent for buildings. It is stated that Fort Des Moines was built from rock quarried at this point. The material is limited as to quantity, and has little to recommend it as regards either looks or quality.

Water Supplies.

In common with other drift covered regions Polk county is well supplied with water. Shallow wells are abundant and easily obtained. The gravel beds and more open portions of the drift afford valuable water horizons. Below the drift water can commonly be found in the coal measures, but it is in such cases so impregnated with minerals in solution as to be unpalatable. In the underlying limestones of the Mississippian water has been obtained at several points. The quality is usually excellent. The most complete record of the lower water horizons available is that obtained from the Greenwood park well.

The well obtains its water supply from the Saint Peter sandstone at a depth of 2,025 feet, the elevation being 872 feet and the water head 827 feet A. T. Water was first struck in the Mississippian beds between 498 and 668 feet below the surface. This water rose to 842 A. T. and was heavily charged with sulphurated hydrogen (hydrogen sulphide). Apparently minor flows were encountered at 1,011 to 1,208 feet and in the

Niagara at 1,425 water rose to the surface and overflowed in a quarter inch stream. The flow now used is from the Saint Peter. It was tested by pumping fifty-two gallons per minute for eighteen hours, in which time the water was lowered 125 feet, but rose again when pumping ceased. At 2,208 feet in the New Richmond a stream with lower head was struck and the water fell from 866 to 822 A. T. At 2,331 it fell to 812, indicating a vein in the lower Oneota. No other fluctuations were observed and on the completion of the well the water rose to its present level.

At the court house there is an artesian well of small flow. It is 580 feet deep and probably derives its water from the Mississippian or from the beds immediately above that formation.

Near Saylorville (Tp. 79 N., R. XXIV W., Sec. 12, Se. Qr., Ne. ¼) a boring was put down to a depth of 1,800 feet, but no reliable data regarding it are available. In the vicinity (Sec. 3, Ne. qr., Se. ¼) is a flowing well less than 400 feet deep and probably deriving its water from the Mississippian or the basal coal measures. Its discharge is given as above 5,000 gallons per hour.

Natural Gas and Oil.

From time to time finds of gas and oil have been reported from the northern portion of the county. In the year 1895 such a discovery was reported from the farm of Mr. Henry Davis located about seven miles northeast of Des Moines. Some years since a similar discovery was made near Saylorville and an exploring company did some deep boring in search of larger supplies. So far as can now be determined their search was wholly unrewarded.

In considering these reported occurrences it should be remembered that the region is within the area covered by the Wisconsin drift and that below the latter a forest bed is quite generally present. The decomposition of the buried vegetal matter at this horizon is an ample source for all the gas

or oil yet found. In no case, so far as reported, has gas been found in the rock. In every instance it occurs at slight depth in the drift. The assumption that it came up to its present position and had its origin in the rocks below is wholly unsupported by facts and entirely gratuitous. So for as present knowledge extends there are no reasons for expecting large supplies of either gas or oil within the county, though it is not impossible that some gas may be found. The gas wells of the drift have at several points in this and other states proven sufficiently productive to be of value for domestic purposes, but not for any thing more. In Kansas the lower portion of the Des Moines formation, known as the Cherokee shales, has produced both gas and oil. In that state the distribution of these materials is quite irregular, but is limited to those portions of the field where the shales are under cover. Since they crop out at the surface in Polk county they have probably long since lost any gas which they may have once contained.

ACKNOWLEDGMENTS.

The Survey is under obligations to a large number of individuals for aid in the preparation of the report. Summing up, as it does, the present development of a number of different industries, it has required the co-operation of the coal operators, brick manufacturers and others engaged in the development of our mineral resources. The cordial aid given by them to the Survey in its work throughout the state has been a constant encouragement. The miners and manufacturers of Polk county have proven no exception, but have cheerfully given information upon all points, so far as they were able. It is a pleasure to acknowledge this aid, without which the report would have lacked much. Among the many, Mr. Thomas L. Wood of the Carbondale Fuel Co., Mr. C. J. Carlson of the Eureka, Mr. J. D. Stockton of the Clifton, and Mr. S. W. White of the Crescent, together with the officers of the Gibson, Christy, Eagle, Bloomfield and other coal com-

panies, have been particularly helpful. Mr. Walker of the Iowa Brick Co., Mr. Flynn of the Des Moines Brick Manufacturing Co., and Mr. McGorrisk of the Capital City have given most important information. The various members of the Survey have generously aided the work at all points. Both Professor Calvin and Mr. Leonard have given much assistance both in the office and in the field. The description of the clay industries is largely from the notes of Mr. E. H. Lonsdale. Professor Norton studied the Greenwood Park well drillings so carefully collected by Mr. T. Van Hyning.

To Dr. Charles R. Keyes, now State Geologist of Missouri, and formerly Assistant State Geologist of Iowa, the author is peculiarly indebted. While living at Des Moines, and before the organization of the Survey, Dr. Keyes collected many notes upon the geology of the county, a portion of them appearing in his report upon the coal deposits of the state. Upon his departure he generously turned over to me these notes, and they have been freely used in the preparation of this report. The parts of the paper specifically credited to him form but a small portion of his contribution. It was under his guidance that the study of the Iowa coal measures was begun and prosecuted for some years, and I must always feel very largely indebted to him for what I may know of the subject. In the present case he has not only furnished notes and suggestions but has also kindly revised the manuscript.

To Professors Chamberlin and Salisbury of the University of Chicago, the author is indebted for very many helpful suggestions. Professor Chamberlin spent some time in the field with me, and later read much of the manuscript.

GEOLOGY OF GUTHRIE COUNTY.

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CONTENTS.

INTRODUCTION.

LOCATION AND AREA.

Guthrie county lies in the west central portion of the state, being in the fourth tier of counties east of the Missouri river, and occupying a similar position with reference to the southern boundary of the state. Carroll and Greene counties bound it on the north, Dallas lies to the east, Adair joins it on the south and Audubon on the west. It includes sixteen congressional townships and is divided into an equal number of civil townships. Owing to the presence of a correction line the townships of the southern tier are irregular in size and position. The county includes 593 square miles, of which a very small percentage only is unavailable for farming.

PREVIOUS GEOLOGICAL WORK.

Although Guthrie county offers exceptional facilities for geological research along certain lines, it has never been studied in great detail. Both Dr. C. A. White and Mr. O. H. St. John, in the course of their work in Iowa, spent some time in the county, and to them our previous knowledge of the region is very largely due.

Dr. White announced the discovery of Cretaceous rocks within the limits of the county in 1868.* Mr. St. John, in the season of 1867, spent some time in the region, his preliminary report being published in 1868.† In the final reports of the survey numerous incidental references were made to the rocks of Guthrie county by Dr. White, and a rather full description of its geology was given by Mr. St. John.‡ At the time this work was carried on the problems of the drift were very imperfectly understood and many wrong conceptions obtained, so that what was then written about the surface materials is in some respects misleading. The first special study of the glacial deposits of this county was that of Mr. Warren Upham

*Proc. Amer. As. Adv. Sci., 1868, XVII, 326-327. 1869.

†First and Second Ann. Rept. State Geologist, pp. 173-201. Des Moines, 1868.

‡Geol. Iowa, II, 95-130. Des Moines, 1870.

direction. It is also probable that there is a slight dip in the same direction, though this is not great, and west of the Des Moines the lower rocks are essentially horizontal, as has been shown by Norton,* and as is indicated by the fact that the base of the Earlham limestone, 1,000 feet above sea level at Earlham, is found at Stuart at about 915 A. T.

The Carboniferous rocks occuring at the surface represent the upper series which has been called the Pennsylvanian by Branner, but is more generally known as the Coal Measure series. The latter name is hardly ideal for the reason that the term is used in different parts of the United States to refer to strata of widely differing age and position. For this reason also it is thought better to use the term Des Moines and Missourian to refer to the two divisions of the series found in Iowa rather than the older terms Lower and Upper Coal Measures.

DES MOINES FORMATION.

In Guthrie county the beds present were referred by St. John mainly to the Middle Coal Measures,† though the presence of both the Upper and the Lower was recognized.‡ It was principally from the exposures in Dallas and Guthrie counties that the general section of the Middle Coal Measures§ was built up by that author.

In the course of the present work in Polk, Guthrie, Dallas and Madison counties it has been found necessary to make certain changes in this general section. As given by St. John it included forty-four members divided into three general divisions, an Upper, Middle and Lower respectively. If one will take the plate published to illustrate the section‖ and making proper allowance for the variation in character along individual horizons, compare the Upper and Lower divisions he can hardly fail to be struck by the similarity. In each

*Iowa Geol. Survey, vol. VI, 328-334. 1897, pp.

†Geol. Iowa, II, 104. 1870.

‡Op. Cit., 105, 128.

‡Geol. Iowa, I, 272-283. 1870.

‖Opposite p. 272, Op Cit.

case there are three coal horizons separated by about the same distances. In each case the sequence above and below the coal horizons is closely similar. The limestone bands are found in similar development and order in each division. The heavy sandstone (number 35) which forms such a well characterized horizon in southeastern Guthrie county has its corollary in the lower division. For the purpose of making this clearer, the following table has been prepared, the data being taken from the plate mentioned.

UPPER DIVISION.		LOWER DIVISION.	
44.	Arenaceous shales and sandstone.	18.	Sandstone.
43.	Bituminous shales.	17.	Shales, blue and yellow.
42.	Lonsdale coal	16.	Wheeler coal.
41.	Shales, light and blue.	15.	Shales, red and yellow.
40.	Limestone (5 feet).	14.	Limestone (3 feet).
39.	Shales, light, red, blue, arenaceous.	13.	Shales, blue and yellow.
		12.	Shales, calcareous, local.
		11.	Shales, blue, yellow.
38.	Limestone (2 feet).	10.	Limestone (6 in +).
37.	Bituminous shale	9.	Bituminous shale.
	Coal.	8.	Panora coal.
36.	Shale, yellow and blue.	7.	Shales, variegated.
35.	Sandstone (10 feet).	6	Sandstone (10 feet).
34.	Shales, arenaceous, yellow and blue.	5.	Shales, light and dark blue, local bituminous shales with fossils at base.
33.	Marshall coal.	4.	Lacona coal.
32	Shales, blue and yellow.	3.	Shales, light and blue.
31.	Limestone, impure, fragmentary.	2.	Limestone, compact, gray.
30.	Shales, variegated.	1.	Shales, variegated.

The similarity of sequence here is certainly striking. There are variations in the thickness of the individual members not shown by the table, but these variations are not greater than can be found in the field by careful tracing of individual layers from point to point. In view of the general character of the Des Moines coal measures it is the persistence rather than the reverse which becomes noticeable. The similarity in the fossils obtained from corresponding beds is no less striking, as may be seen by comparing St. John's published lists and

morainic topography extends but a short distance, and usually the greater roughness along the edge of the Wisconsin drift is, in this county, due to the nearness to the Raccoon river and the consequent greater erosion. Directly south of Bayard and between Willow creek and the river is a ridge rising fifty feet above the drift plain. It is composed of Cretaceous sandstone, and the prominence is probably due to the persistence of preglacial topography.

The influence of the Wisconsin ice shows itself in the Raccoon valley in two ways. At many points there is a gravel terrace which rises twenty to twenty-five feet above the water. It is usually wider than the widest alluvial plain, and is genetically related to the Wisconsin drift. At Rock Bluffs and along the lower portion of the Raccoon river the ice pushed over into the valley, so that one finds a bluff face which has not been modified and does not show normal erosion. In general, however, the Raccoon valley is but slightly influenced by the Wisconsin ice.

The topography of the area covered by the Wisconsin drift has not been fashioned by streams and it has been only slightly influenced by them. In this regard it stands in sharp contrast with that outside the Wisconsin limits. In this southern portion of the county the land forms are, as has been said, erosion forms. They have been developed upon the drift surface by the action of weathering and running water. In part, this water has been concentrated in gullies and ravines and has taken the form of rivulets, creeks and rivers. In part it has acted as a broad sheet over wide surfaces. By these two methods of erosion the land forms have been developed. The two different modes of action have produced two different forms of surface which in cross-section yield different curves. These curves, as developed in the region under discussion, are so well developed, so characteristic, and reveal this region so clearly that a brief description of them may not be out of place.

The materials in which the erosion has taken place, while somewhat diverse, are in a general way homogeneous. They include drift, soft sandstones and shales. These materials weather and erode differentially, and yet, in a broad way, the action is uniform. The differences induced by differential weathering are slight, are not at first operative, and in the end serve merely to modify the general results. The erosion dates in the main from the retreat of the Kansan ice, and with exceptions to be noted later, the surface may be considered to have been at that time a fairly even drift surface. The region is then one in which there has been long continued erosion upon an even plain of relatively homogeneous material. The erosion has been so long continued that the country is almost wholly reduced to slope. The slopes, however, are not all of the same character. The general surface is trenched by a system of major valleys, which are cut about 150 feet below the general upland level. These larger valleys have a well developed system of secondaries which in turn support tertiaries, all developed regularly, and together covering the country with a network of water courses and ravines. Back from each valley proper there is a long gentle slope to the divide between it and some neighboring valley. The slopes near the streams are quite pronounced, often becoming well marked bluffs. The general upland slope is very gentle, and often is hardly to be noticed. The upland slope and the upper portion of the bluff slopes are convex. The lower portion of the bluff slope where it joins the flood plain is concave. The convex slopes above lose their convexity and approach more nearly to a plain as the distance from the bluff increases. The concave slopes below obey the same law. One is the reverse of the other, the two meeting in the sharp bluff face. The concave slopes are not so conspicuous and are apt to be overlooked. As one passes over the country it is the long, sweeping convex slopes, merging by degrees into the almost plain lines of the upland, which make the greatest impression. It has been customary to consider the convex slope as the

product of weathering* and the concave slope as the curve of erosion.† For the region under discussion, however, this does not seem to hold true. The very gentle upland slope, hardly to be called a curve, though merging into the convex curve of the bluff, is developed in the region which has been moulded by weathering agencies. The sharply convex slope of the bluff is at the point where erosion is most active. The concave curve appears only where there has been deposition coupled with erosion. This seems to hold true for the whole region, and one is forced to reject the concave as the normal curve of erosion if this region represents average conditions. This does not of course apply to the general curve of the whole of a river profile which is well known to be concave; nor does it apply to curves produced by the erosion of alternating hard and soft strata where concave curves are often produced in the manner discussed by Noe and Margerie.‡

McGee§ has noted the prevalence of concave forms on the land, and has interpreted them as expressing the "law of land profiles" as contrasted with the "law of water course profiles," yielding concave curves. Gannett‖ seems to have had much the same idea in speaking of the convex curve as the "curve of the terrain," and the concave as the "curve of the valley." As has been shown elsewhere the normal processes of erosion on homogeneous material tend to develop convex curves.¶ In the streamways the potential excess of transportation over erosion leads to undercutting and the development of concave curves. These are essentially similar to the curves originating through alternating hardness of strata. The concave curves along the valley sides arise, however, as a result of deposition.

The sandstones of the Dakota, the limestones of the Missourian, and the sand and limestones of the Des Moines all tend

*Hicks: Science, Bul. Geol. Soc. Am., vol. IV, p. 135. 1893.
†Gilbert: Geol. Henry Mts., p. 110. 1880.
‡Noe et Margerie, Les Formes du Terrain, p. 24, 28, *et seq.* Paris, 1888,
§Eleventh Ann. Rept: U. S. Geol. Surv., p. 246. 1891.
‖Mon: XXII, U. S. Geol. Surv., p. 143. 1893.
¶Iowa Geol. Surv., vol. VI, pp. 449-458. 1897.

to break up the general curves developed on the drift. Where the indurated rocks occur along the streams, they usually show as shoulders on the valley side, or as steep precipitous bluffs. The presence of the Cretaceous is frequently detected by these shoulders, of which an excellent example may be seen about a mile south of Dale City on Beaver creek. The sandstone is here grassed over but shows a well defined bench which is particularly well shown where minor streams come down the bluff face. The drift itself, however, often shows exceedingly steep slopes, so that the latter can not always be taken as indicative of the presence of rock.

TABLE OF ELEVATIONS.

In the following table is given the elevation of most of the towns in the county or near its borders. The figures are taken from the profiles of the Chicago, Milwaukee & St. Paul and the Chicago, Rock Island & Pacific railways, and revised to agree with Gannet's Dictionary of Altitudes.

Adair	1,415
Bagley	1,166
Bayard	1,237
Casey	1,237
Coon Rapids	1,178
Dexter	1,157
Glendon	1,047
Guthrie Center	1,075
Herndon	1,064
Jamaica	1,041
Menlo	1,271
Montieth	1,045
Stuart	1,216

DRAINAGE.

The streams of Guthrie county belong to two separate systems. In the southwestern portion of the area are a few minor waterways which drain into certain tributaries of the Missouri; the major portion of the county is drained by various branches of the Raccoon river, which itself empties into the Des Moines, through which the waters find their way into

the Mississippi. The watershed between the tributaries of the two great master streams of the continental interior traverses the country. In Bear Grove township it separates the headwaters of Troublesome creek from those of Seeley creek, and in Grant township it forms a barrier between Crooked creek and the upper branches of Middle river. At Adair, near the southwestern corner of the county, the watershed is crossed by the Chicago, Rock Island & Pacific railway at an elevation of about 1,400 feet. From this point the country slopes down toward the east to the Mississippi river at Rock Island 542 A. T., in a distance of about 200 miles measured direct. Toward the west the surface declines to the Missouri, 962 A. T. at Omaha, in about seventy miles. The watershed is not a marked physiographic feature but may be traced by the heading of the streams.

The pronounced differences in topography already noted are reflected in the streams of the county. The area covered by the Wisconsin has immature drainage. Small lakes and surface pools are found. Swales or sloughs are not uncommon, and the few streams which occur represent the youngest type of newly formed rivers. They have no well marked valleys but flow rather through a series of loosely connected, low-lying swales in the drift. They are rarely timber marked. Such a stream is Mosquito creek in Richland township, flowing into the Raccoon river near Redfield in Dallas county. Willow creek in Highland and Bays branch in Cass township are streams essentially similar except in their lower reaches.

In the area lying without the Wisconsin limits the drainage is much more complete. The county as a whole is traversed from northwest to southeast by both South and Middle Raccoon rivers. These two streams nearly parallel each other the entire distance and are from three to seven miles apart. For more than half the distance the narrow strip of land between the two is cut by Brushy Fork, which runs parallel to the two rivers to near Monteith, where it joins the South Raccoon. These three streams are of the type of long, nar-

row, non-branching streams and, with the exception of South Raccoon, they receive comparatively few tributaries. The latter stream receives a number of branches from the southwest, including Seeley, Bear, Beaver and Deer creeks, Long branch and several minor streams. These tributary streams are of the short, branching type. They divide and sub-divide until the whole area is cut up by a complex network of minor stream-ways such as mark a well developed drainage system.

Between the headwaters of the tributaries of South Raccoon and the Missouri-Mississippi watershed is a narrow strip of country traversed by Middle river and its branches and touched by North river. In general appearance this latter region resembles that drained by the Raccoon river. Middle river is here a very minor stream but in a general way parallels, and may be classed with, the Raccoon.

The county is, then, divided into two areas; one is of immature drainage, coextensive with the Wisconsin area, another of very mature and well developed drainage coextensive with the Kansan loess covered area.

The contrast between the topography and the drainage of the two portions of the county is manifestly largely a contrast of age. Both have the same underlying rocks and structure, both are covered by drift, and both have about the same elevation. One is, however, covered by a later drift sheet than the other, and the differences in drainage and topography are but the expression of this fact. The more complete drainage of the southwest is a result of the greater lapse of time since the retreat of the ice.

The streams of the extra-Wisconsin area are in the main of post-Kansan, pre-loess age. Portions of some of the valleys seem to be earlier than the drift, but the system as a whole is later. It is pre-loessial since the loess runs down into and partially fills the valleys. It is not earlier than the drift since the divides, so far as can be ascertained, are not made of drift-veneered rock but are almost wholly drift. The surface of the rock seems to have been a fairly even plain when the ice

invaded it. The valleys present at that time, while to some extent taken advantage of by the present streams, do not seem to have been generally perpetuated.

The most striking anomaly in the drainage is the parallelism of the three streams, Middle and South Raccoon and Brushy Fork. No very satisfactory reason for this parallelism can be offered. The streams bear no definite relations to the underlying rocks since they maintain their courses regardless of both lithological variations and changes of dip and strike. They were not conditioned by the edge of the Wisconsin since the valleys were cut much as they are now before the Wisconsin came into the region, and furthermore because the later ice did not reach Brushy Fork or South Raccoon, and only touched a portion of the valley of Middle Raccoon. Since the general direction seems to have been developed upon the Kansan drift before the streams had cut through it, it is probably due to some factor of the Kansan ice, possibly indicating a series of halts in the retreat of the ice with the development of successive streams parallel to its front.

STRATIGRAPHY.

GENERAL RELATIONS OF STRATA.

The rocks of Guthrie county include representatives of the three great groups, Paleozoic, Mesozoic, and Cenozoic. The first is represented by the shales, coals, limestones and sandstones of the Carboniferous. These beds are exposed along the streams and occur immediately beneath the drift throughout the eastern portion of the county. Over them and beneath the drift of the central and western portions, the Mesozoic is represented by the sandstones, gravels and clays of the Cretaceous. Over the whole county, mantling and concealing the indurated rocks, are the unconsolidated gravels, sands, clays and drift deposits of the Pleistocene. The Carboniferous, Cretaceous and Pleistocene are separated from each other by unconformities indicative of long time intervals and much erosion. The rank of the different beds is indicated in the accompanying table.

GROUP.	SYSTEM	SERIES.	STAGE.
Cenozoic.	Pleistocene.	Recent.	Alluvial.
		Glacial.	Wisconsin Iowan Kansan.
Mesozoic.	Cretaceous	Upper Cretaceous.	Dakota.
Paleozoic.	Carboniferous	Upper Carboniferous.	Missourian. Des Moines.

CARBONIFEROUS.

The Carboniferous of the Mississippi valley is made up of two series of strata. The lower or Mississippian series does not occur in Guthrie county, being buried by later beds. It is known throughout this region from well borings only. No record of any well within the county which reached the Mississippian is available, so that the thickness of the coal measures cannot be positively stated. Two well borings in the southwestern portion of Dallas county passed through the coal measures and into the underlying Saint Louis. These indicated a thickness of about 400 to 540 feet of coal measures between the Winterset and Saint Louis limestones. At Des Moines certain borings* show that a total thickness of about the same amount, though the rocks at that place are considerably below the horizon of the Winterset limestone. The Saint Louis was found at a depth of 498 feet, or at 374 A. T. in the Greenwood Park well.†

While the various borings in Polk and Dallas counties do not give uniform results it seems probable that the base of the coal measures lies probably at about 600 A. T., or at a depth of 550 to 650 feet below the upland of the eastern portion of Guthrie county. Farther west this horizon would be reached at greater depth, because of the rise of the surface in that

*Geol. Polk. Co, Iowa Geol. Surv., vol. VII.
†Norton: Iowa Geol. Surv., vol. VI, p. 299. 1897.

direction. It is also probable that there is a slight dip in the same direction, though this is not great, and west of the Des Moines the lower rocks are essentially horizontal, as has been shown by Norton,* and as is indicated by the fact that the base of the Earlham limestone, 1,000 feet above sea level at Earlham, is found at Stuart at about 915 A. T.

The Carboniferous rocks occuring at the surface represent the upper series which has been called the Pennsylvanian by Branner, but is more generally known as the Coal Measure series. The latter name is hardly ideal for the reason that the term is used in different parts of the United States to refer to strata of widely differing age and position. For this reason also it is thought better to use the term Des Moines and Missourian to refer to the two divisions of the series found in Iowa rather than the older terms Lower and Upper Coal Measures.

DES MOINES FORMATION.

In Guthrie county the beds present were referred by St. John mainly to the Middle Coal Measures,† though the presence of both the Upper and the Lower was recognized.‡ It was principally from the exposures in Dallas and Guthrie counties that the general section of the Middle Coal Measures§ was built up by that author.

In the course of the present work in Polk, Guthrie, Dallas and Madison counties it has been found necessary to make certain changes in this general section. As given by St. John it included forty-four members divided into three general divisions, an Upper, Middle and Lower respectively. If one will take the plate published to illustrate the section‖ and making proper allowance for the variation in character along individual horizons, compare the Upper and Lower divisions he can hardly fail to be struck by the similarity. In each

*Iowa Geol. Survey, vol. VI, 328-334. 1897, pp.

†Geol. Iowa, II, 104. 1870.

‡Op. Cit., 105, 128.

‡Geol. Iowa, I, 272-283. 1870.

‖Opposite p. 272, Op Cit.

case there are three coal horizons separated by about the same distances. In each case the sequence above and below the coal horizons is closely similar. The limestone bands are found in similar development and order in each division. The heavy sandstone (number 35) which forms such a well characterized horizon in southeastern Guthrie county has its corollary in the lower division. For the purpose of making this clearer, the following table has been prepared, the data being taken from the plate mentioned.

UPPER DIVISION.	LOWER DIVISION.
44. Arenaceous shales and sandstone.	18. Sandstone.
43. Bituminous shales.	17. Shales, blue and yellow.
42. Lonsdale coal	16. Wheeler coal.
41. Shales, light and blue.	15. Shales, red and yellow.
40. Limestone (5 feet).	14. Limestone (3 feet).
39. Shales, light, red, blue, arenaceous.	13. Shales, blue and yellow.
	12. Shales, calcareous, local.
	11. Shales, blue, yellow.
38. Limestone (2 feet).	10. Limestone (6 in +).
37. Bituminous shale	9. Bituminous shale.
Coal.	8. Panora coal.
36. Shale, yellow and blue.	7. Shales, variegated.
35. Sandstone (10 feet).	6 Sandstone (10 feet).
34. Shales, arenaceous, yellow and blue.	5. Shales, light and dark blue, local bituminous shales with fossils at base.
33. Marshall coal.	4. Lacona coal.
32 Shales, blue and yellow.	3. Shales, light and blue.
31. Limestone, impure, fragmentary.	2. Limestone, compact, gray.
30. Shales, variegated.	1. Shales, variegated.

The similarity of sequence here is certainly striking. There are variations in the thickness of the individual members not shown by the table, but these variations are not greater than can be found in the field by careful tracing of individual layers from point to point. In view of the general character of the Des Moines coal measures it is the persistence rather than the reverse which becomes noticeable. The similarity in the fossils obtained from corresponding beds is no less striking, as may be seen by comparing St. John's published lists and

as will be brought out later. Below number 30, as given above, is a thin shale sequence resting upon a buff fragmentary limestone (number 26), which is one of the easiest horizons to recognize in the field. This in turn rests on a sequence of variegated predominantly arenaceous shales corresponding in character in a general way to the main portion of St. John's middle division.

Numbers 26 to 44 of St. John's section may be readily recognized throughout the southeastern portion of Guthrie county and will be illustrated in the sections to follow.

The lower beds of this section are seen on Middle Raccoon river near the old Tann mill, southwest of Linden (Tp. 79 N., R. XXX W., Sec. 25, Ne. qr., Sw. ¼). As now shown the section is in part talus covered, but at the time St. John visited it was quite well exposed. He gives* a careful section which is reproduced below with a few changes necessitated by present studies. Opposite the numbers of the section are numbers corresponding to the place of the bed indicated in the general section. The beds best exposed now are numbers 10, 12 and 15.

TANN MILL SECTION.

GEN'L SECTION NUMBER.			FEET.	INCHES.
	16.	Drift, Kansan	6	4
40	15	Limestone, thin bedded, buff with *Productus cora*, *Chonetes granulitera* and *Athyris subtilita*	1	6
39	14.	Shales, gray, argillaceous; becoming blue below and carrying *Lopophyllum*, *Productus punctatus*, *P. longispinus*, *Chonetes granulifera*, *Derbya crassa*, *Spirifer kentuckensis*, *S. plano-convexa*, *Athyris subtilita*, *Hustedia mormoni*, *Bellerophon carbonaria*, etc	20	
38	13.	Limestone, nodular, impure		6
37	12.	Shales, bituminous, mixed with impure coal	1	6
36	11.	Shales, light colored	8	
35	10.	Sandstone, coarse, yellow, with flakes of coaly matter and remains of poorly preserved Neuropteris	10	

*Op. Cit., p. 112.

GEN'L SECTION NUMBER.			FEET.	INCHES.
34	9.	Shales, arenaceous, blue and yellow	3	
33	8	Coal, impure		6
32	7.	Shales, dark and light blue	7	
31	6.	Limestone, thin, irregular	1	
	5.	Shales, blue	2	
	4.	Limestone, earthy, irregularly bedded with *Productus muricatus*, *P. cora*, *Derbya crassa*, *Athyris subtilita*, *Spirifer plano-convexa*, *Rhynchonella uta*, etc	1	6
	3.	Shales, blue	1	
	2.	Limestone, impure, many *P. cora*, *P. muricatus* and *Chonetes mesoloba*	1	
	1.	Shales, blue and gray, exposed about twenty-five feet above the river	2	

About three quarters of a mile north of the exposure just described, Mr. St. John found the same beds exposed along Hooks branch at a somewhat higher level. Under a coal seam taken to represent number 8 were three limestone beds corresponding to numbers 2, 4, and 6. Below these the following section extended down to the river.*

HOOKS BRANCH SECTION.

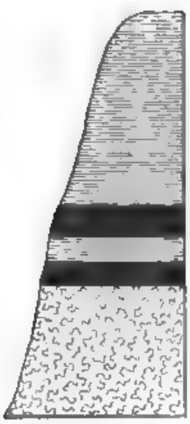
		FEET.
11.	Shales, red, blue and yellow in color, with nodular bands; *Productus muricatus*, *P. cora*, *Athyris subtilita*	6
10.	Limestone, impure, shaly	2
9.	Clays, blue and reddish, with a band of fosiliferous shale near the top, carrying *Spirifer plano-convexa* and Petrodus	8
8.	Shales, in part argillaceous, blue to red; in part arenaceous, yellow, and becoming shaly sandstone at the top	17
7.	Sandstone, compact to shaly, gray, with *Productus cora*, *Derbya crassa* (?) Myalina, sp. und	1
6	Clays, yellowish and blue, gritty, merging above into soft, gray, arenaceous shale	12- 13
5.	Unexposed	15- 25
4.	Shales, blue	15
3.	Shales, calcareous and bituminous, dark gray to drab; *Productus muricatus* very abundant, *Derbya crassa* (?) *Athyris subtilita* and a minute gasteropod	1½
2.	Coal	½+
1.	Shales, blue to river	1

*Op. Cit., p. 115.

Passing east from the Tann Mill section there are numerous exposures along the river. The strata rise and pass over an anticline, as has been worked out by Mr. A. G. Leonard.* Beyond this anticline the general sequence already noted is found in the hill tops and below the sandy member corresponding to the "Middle" division (19–26) of St. John is a series of beds extending along the river down to and connecting with the section worked out by Keyes.† These lower beds as found by Mr. Leonard do not correspond to beds 1–18 of St. John's section, and can not be correlated with them. The Guthrie county exposures do not show anything corresponding to them, and the revised section leads inevitably to the conclusion that the lower portion of the old section is in error. This conclusion must rest mainly upon the evidence from Dallas county since the exposures between the Tann Mill section and Panora are not sufficient to allow very exact correlation. Such as occur, however, accord nicely with the view that the exposures in and near Panora belong with those of the southern portion of the county rather than below them.

About three miles northwest of the Tann Mill section is a group of small mines, near one of which, the Dygart (Tp. 79 N., R. XXX W., Sec. 16, Se. qr.), the following section is exposed not far above the river.

DYGART MINE SECTION.



		FEET.	INCHES.
5.	Shale, exposed	3	
4.	Coal		5
3.	Clay shale		4
2.	Coal		4
1.	Fire clay, exposed	2	

FIG. 67. Bluff at Dygart drift.

*Report on Dallas county not yet published

†Bull. Geol. Soc. Am., II, pp. 277-292, 1891. Iowa Geol. Surv., I, 94-105. 1893.

Still nearer Panora, at the mouth of Bays branch, is a second group of small mines, all of which are now abandoned. The coal formerly worked has been called the Panora horizon, but seems to represent number 37 of the general section. It is exposed in the bluffs not far above the river. The following section at this point is given by Keyes.

		FEET.
7.	Drift	4
6.	Limestone, impure	3
5.	Shale, dark drab	8
4.	Limestone, impure, bituminous	½
3.	Shale, black, carbonaceous	1½
2.	Panora coal	1
1.	Shale, light colored and variegated; exposed,	10

There are good exposures along the river in the vicinity of Panora, and the mining development there has made known something of the geology of the underlying beds. At the clay pit of the Panora Brick & Tile Co. is shown an impure coal with bituminous shale, which marks the horizon just noted. The limestones which usually accompany this coal bed are not well shown. The section varies in different parts of the pit, but is in general as follows:

		FEET.
3.	Shale clay, argillaceous, red	12
2.	Coal and bituminious shale	2
1.	Shale, argillaceous-sandy, blue to white with irregular bands of calcareous material; exposed to within six feet of the river	18

Near this section and above the coal is a small quarry in a gray sandstone. The latter is irregularly bedded and broken. It is coarse-grained and quite full of broken bits of plant remains. Similar stone is exposed in the old quarries west of town, where the following beds may be examined.

		FEET.
3.	Drift	6 +
2.	Shale, sandy, light colored	2- 4
1.	Sandstone, coarse-grained to conglomeratic, with bituminous shaly partings	6-10

The position and significance of this sandstone will be discussed later.

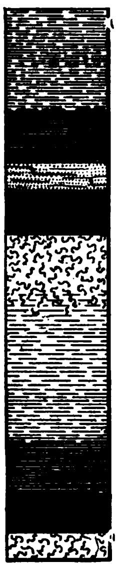
On the south side of the river coal has been mined for some time. Three seams are known to be present. In the top of the hills is a very thin seam which here is of no value. It apparently represents the horizon of the Lonsdale coal. About twenty to twenty-five feet above the river is the coal which has been called the Panora, but which, as already mentioned, probably represents number 37 of the general section. It was this seam which was worked at the time St. John visited the region. Thirty feet below the river is the bed now worked. The mouth of the Reese coal shaft, put down in 1896, is about on a level with the Panora coal. The section afforded by the shaft is as follows:

		FEET.
9.	Drift	6
8.	Limestone	1
7.	Clay shale, red	7
6.	Shale clay, soft	2
5.	Sandstone, white to gray, with flakes of mica	30
4.	Shale, bituminous, fossiliferous, becoming a cannel coal below	10
3.	Coal	1⅔
2.	Fire clay	8
1.	Sandstone	10+

As indicated by this section the beds between numbers 33 and 37 of the general section have thickened very considerably and have also changed a little in character. It will be noted that the sandstone, number 33 of the general section, maintains its position. The thin limestone above is exceptional but not wholly anomalous.

A short distance northwest of town is the mine of the White Ash Coal Co. The shaft is sixty feet deep and the mouth is seventy-five feet above the river, so that in position the coal corresponds more nearly with the Panora seam than with that worked in the Reese mine. Still farther up the river (Tp. 80 N., R. XXXI W., Sec. 24, Nw. qr., Se. ¼) is the Clark mine, the mouth of which is twenty feet above the river. Near the mine the coal measure shales are exposed, with the Cretaceous sandstones and conglomerates overlying them.

The section will be described in connection with the Cretaceous. About three miles beyond, in the neighborhood of Fanslers, is a group of mines which have been in operation for some time. The coal worked lies about fifty feet below the river and is the same at all the mines except the Scott mine, where a second seam has been found a few feet below the one generally worked. The section at the latter mine is as follows:



	FEET.	INCHES.
7. Shale, light colored, argillaceous, sandy in places, exposed	4	
6. Clay shale, dark, fissile	2	
5. Sandstone, "caprock"	1	
4. Coal, containing heart shaped pericas in pyrite, with four inches of shaly material at the bottom	1	10
3. Fire clay and clay shales	10	
2. Coal	1	6
1. Fire clay	1	

FIG. 68. Section of Scott shaft. Fanslers.

This lower coal has not been found at any of the other mines and is evidently a local deposit. The coal measure shales are covered by Cretaceous sandstone. St. John mentions* an upper seam about four or five feet above water level. The bed was thin and is not now worked. The upper seam is about the same distance above the Fansler coal as the one outcropping at Panora is above the coal at the Reese mine. The river runs at only a slight angle with the strike of the beds and there is apparently a dip to the west. The coal

*Opus cit., p. 106. There is evidently a misprint at this point, as the locality mentioned, Tp. 81 N., R. XXXII W., Sec. 19, is far from the river and near no known coal outcropt. It should evidently read Tp. 80 N. The location of Clark's mine, not the present Clark mine, has evidently been confused. If instead of section 24, section 4 be read, the facts fit the description.

present at the two points may be considered as representing the same horizons.

Farther up the river the coal measures are cut out at Rocky Bluff by the Cretaceous. Beyond the bluff the Cretaceous has been cut through by the river and the coal measures are again exposed.

The Wales coal bank is located on the south side of the river (Tp. 81 N., R. XXXIII W., Sec. 33, Ne. qr.). The coal, which is sixteen to eighteen inches thick, rests on shales and lies about twelve feet above the river. Over it are black shales from which St. John* collected *Productus muricatus*, *Derbya crassa* (?) and *Lingula carbonaria*. The coal measures have a thickness of twenty-seven feet above the coal as shown in the air shaft. In the hillside near by there are exposures of the sandstone of the Dakota. A mile or more above the river the coal is again reached by the Perkins drift (Tp. 81 N., R. XXXIII W., Sec. 29). Near the mine (Sec. 20, Sw. Sw.) is a high bluff of Cretaceous sandstone and clay, while in sections 29, 20, 19 and 24, coal has been mined at various points. In section 24, apparently, two seams are present. The one now worked is found by shafts thirty-nine to fifty-six feet deep, and seems to lie about twenty-eight feet below the river. Formerly a surface seam was worked† lying about two feet above the water.

It will be seen from an examination of this section that the usual sequence holds in passing up the river. The beds dip a little to the west, and the shales thicken so that the coal horizons are spread farther apart. The character of the beds changes to the west, new strata appear, and the formation takes more and more the inconstant character usual throughout the Des Moines formation.

In the southern portion of the county along South Raccoon, Long branch, Deer creek and Beaver, there are many exposures showing the beds from the Missourian limestone down to the heavy mass of sandy shales which forms the base of

*Op. cit., 105.
†St. John: Op. cit, 105.

known sequence already described. Throughout the region the basal portion of the Missourian, the Bethany limestone, outcrops in the hills. The streams have cut through it and down deep into the underlying beds. One of the best sections, starting however, some distance below the Bethany, is found along a ravine north of Glendon, and leading down to the river near the old Belle Valley mill site (Tp. 79 N., R. XXX W., Secs. 30-31). The section is made up of numerous scattered outcrops along the hollow, but fitted together gives the sequence nicely.

		FEET.	INCHES.
16.	Limestone, yellow, earthy, corresponding to No. 38 of the general section	1	
15.	Shale, bituminous, with some coal (No. 37)		8
14.	Shale, yellow (No. 36)	5	
13.	Sandstone in hard three inch ledges separated by softer shaly layers (No. 35)	4	
12.	Shale, sandy (partly exposed)	2	6
11.	Coal, Marshall (No. 33)		3
10.	Shale, gray, clayey (No. 32)	1	
9.	Limestone, sandy, with plant remains abundant, Myalina with a narrow accentuated beak frequent, *Nuculana bellastriata* and *Productus cora* (No. 3)	1	6
8.	Shale, blue, clayey	2	
	Unexposed	8	
7.	Shale, sandy, yellow	2	
	Unexposed, probably as above	10-15	
6.	Limestone, fragmentary, with many well rounded pebbles of ash gray limestone of conchoidal fracture bedded in reddish earthy limestone matrix; carrying *Athyris subtilita*, *P. muricatus*, moderately common and a dermal tubercule of Petrodus (No. 26)	3	
5.	Shales, argillaceous, blue	6	
4.	Sandstone, fine-grained, ripple marked		3
3.	Shales, sandy, with a slight dip up the river, imperfectly exposed	50‡	
2.	Clay, yellow to gray		6
1.	Coal in two benches as follows: Coal, 4 inches; clay, 5 inches; coal, 3 inches	1	

Below the coal there are no exposures along the stream down to where it empties into the river. From the presence of the great thickness of sandstones and shales above the coal and below the fragmentary limestone, it is probable that the coal found belongs to the Redfield horizon. The base of this stream is probably thirty or forty feet above the river. Passing up the latter a half mile one comes to the exposure at the site of the old mill, an outcrop which will be later described.

Corresponding beds are seen at many points south and east. Near Dale City the heavy sandstone (number 35) with the black shale and limestone (numbers 37 and 38) above it is found exposed. At this point a boring was put down some time since by John Lonsdale & Sons. The record reproduced below by their courteous permission shows a number of coal seams, the more important being at 264 and 318 feet. The head of the boring is estimated by Mr. Charles Lonsdale to have started some feet below the Marshall coal.

		FEET.	INCHES.
69.	Drift	12	
68.	Shale, red, blue and brown	19	
67.	Sandstone, light gray	3	
66.	Shale, gray	11	7
65.	Shale, gray, dark	10	7
64.	Coal		2
63.	Fire clay		4
62.	Shale, with impure coal in alternate layers	1	10
61.	Yellow stone		1
60.	Fire clay		6
59.	Shale, dense gray with traces of coal	4	9
58.	Sandstone	1	4
57.	Shale, blue	4	
56.	Shale, dark gray	14	4
55.	Sandstone, white	6	6
54.	Shale, blue	2	
53.	Limestone		2
52.	Shale, yellow	1	4
51.	Limestone		9
50.	Shale, gray		3
49.	Limestone		9
48.	Shale, blue		2

		Feet.	Inches.
47.	Limestone	1	4
46.	Shale, brown	2	
45.	Shale, blue, black at bottom	3	7
44.	Limestone, gray, very hard		10
43.	Slate, black	2	
42.	Coal		4
41.	Shale, light blue	15	
40.	Shale, brown	2	6
39.	Shale, variegated	7	
38.	Shale and limestone in thin layers	3	4
37.	Shale, variegated	8	
36.	Shale, blue	25	3
35.	Shale, yellow	1	9
34.	Limestone, buff		4
33.	Shale, gray, blue black at bottom	6	8
32.	Coal	1	4
31.	Shale, blue fire clay at top	6	10
30.	Limestone, gray	1	8
29.	Sulphur band		2
28.	Sandstone, fine-grained	11	
27.	Limestone, very hard	3	1
26.	Sandstone, white	2	6
25.	Shale, variegated	4	9
24.	Sandstone, gray	7	2
23.	Shale, gray	3	9
22	Sandstone, gray	3	9
21.	Shale, blue gray	10	10
20.	Shale, gray	23	
19.	Coal	2	6
18.	Fire clay		6
17.	Shales, light and gray	17	10
16.	Sandstone		8
15.	Shale	1	3
14.	Limestone, brown	2	
13.	Shale, dark	1	2
12.	Black stone		2
11.	Slate, bluish black	5	8
10.	Sulphur band		1
9.	Shale, blue	1	5
8.	Shale, blue and gray fire clay at top	17	8
7.	Coal	3	4
6.	Shale	1	6
5.	Coal	1	
4.	Shale		8
3.	Coal		10
2.	Shale, light and dark	17	5
1.	Shale, dark blue	2	

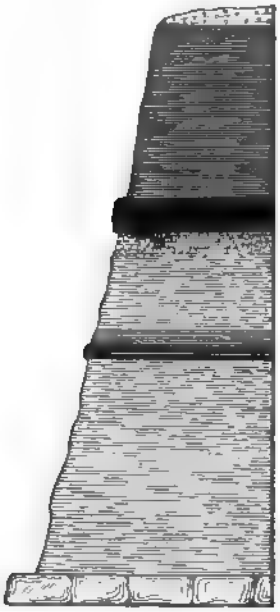
South of Dale City (Sec. 6, Tp. 78 N., R. XXX W.) a roadside gully shows the presence of the limestone and underlying coal and shale forming numbers 38 and 37 of St. John's section. On Hog branch, near the road crossing in section 6, is an exposure showing the Marshall coal in its usual development, with shales above and below. There is, however, an unusual three inch band of limestone in the shales about four feet above the coal. In the bed of the Raccoon river, just below the mouth of the branch (Tp. 78 N., R. XXX W., Sec. 5, Sw. qr., Sw. ¼) is a limestone corresponding to number 31. Near the head of the branch (Sec. 7, Ne. of Se.) the Muldoon mine is opened in a coal probably the Lonsdále, and not far northwest (Tp. 78 N., R. XXXI W., Sec. 12, Sw. of Sw.) the Driscoll mine works the same bed. The Marshall coal and overlying beds is seen again on the south side of the river, about two miles below Dale City (Tp. 78 N., R., XXX W., Sec. 4). On the opposite side of the river the heavy sandstone, number 35, is well shown and in the hillside above deserted dump heaps mark the level of the Lonsdale coal. The latter is best seen along Deer creek.

Near the west line of Penn township (Tp. 78 N., R. XXX W., Sec. 18, Sw. qr., Sw. ¼) is the Lonsdale mine, a shaft sunk near the base of the Winterset limestone. The coal lies thirty feet below the lowest bed of the Missourian limestone, a soft white sandstone intervening. The coal itself averages twenty inches in thickness. It is divided by two clay bands as shown below:

		INCHES.
5.	Coal	12
4.	Clay	2
3.	Coal	4
2.	Clay	½
1.	Coal	4

The same seam has been opened at a number of points along the river. The Lamb mine, directly north of Stuart (Tp. 78 N., R. XXX W., Sec. 20, Ne. qr.), was worked for some time. It was found here that the lower bench dipped to the

east, though this may be a local development. Near this mine the coal is exposed in the creek as shown in the following sketch.



		Feet.	Inches.
8.	Drift	10	
7.	Shale, bituminous to drab above	4	
6.	Coal		10
5.	Fire clay	2	
4.	Shale, light colored		8
3.	Coal, with shaly partings		3
2.	Shale, light colored	5	
1.	Limestone, fossiliferous	4	

Fig 69. Section of bluff on Deer creek.

The thickness of the partings between the two benches of coal varies somewhat. Above the shale covering the coal is a buff clay shale running up into sandy shale and sandstone. Below the limestone seen in this section (number 40 of general section) is a bed of variable shale of some thickness.

Near Glendon, coal measures are exposed along the streams, the Cretaceous outcropping well up in the hills. In a cut on the Chicago, Rock Island & Pacific railway not far north of the town (Tp. 79 N., R. XXXI, W., Sec. 36, Se. qr., Sw. ¼) there is an exposure showing both formations.

GLENDON SECTION.

		Feet.
6.	Sandstone, soft, yellow to red, irregularly bedded	2
5.	Clay, yellow, free from grit, much like geest	1½
4.	Limestone, brecciated, gray, with common coal measure fossils	2
3.	Shales, yellow, clayey	8
2.	Limestone, soft, sandy	½
1.	Shale, clayey, red to greenish	12

Numbers 1 to 4 may be referred to the coal measures. They have equivalents at other points in the vicinity and on Spring branch (Tp. 78 N., R. XXXI W., Sec. 3, lot 12) a thin coal seam, supposed by St. John to represent the Marshall horizon, was formerly exposed.*

A lower bed, said to have been two feet six inches thick, was at one time worked at a depth of 100 feet, and a thicker bed, four and one-half feet, was reported sixty to seventy feet still lower.

Outcrops of coal measure strata are reported along Beaver creek for a distance of two miles west of this point. At one point (Tp. 78 N., R. XXXI W., Sec. 5, lot 4) a fourteen-inch seam of coal was formerly worked. Coal measures are also reported on South Beaver (Sec. 5, lot 19) and on Spring branch (Tp. 78 N., R. XXXI W., Sec. 16, Ne. qr., Sw. ¼) a thin seam was formerly reached by drifting.

Along Middle Raccoon and Brushy Fork there are no good coal measure outcrops, though coal is mined on the former near Guthrie Center (Tp. 79 N., R. XXXI W., Sec. 17, Sw. qr.) and on the latter southwest of Bayard (Tp. 80 N., R. XXXII W., Sec. 5, Sw. qr.). At the Guthrie Center mine the coal is eighteen inches thick, and is found at a depth of eighty-seven feet; the overlying strata being shale and sandstone. This is probably the same vein that was formerly worked at Glendon. In a boring put down some years since on the Tracy, now Stover and Metz land, a mile west and half a mile north of the court house at Guthrie Center, the corresponding vein was struck at 132 feet. As reported by Hon. Charles Ashton, the bed is twenty inches thick and lies below six and one-half feet of black slate. Below this bed of coal, at a depth of 197 feet, a second vein four feet and five inches thick, and covered by a soft white clay, was reported. About five feet below another bed of coal and black clay was reported. The drilling was done just west of the Raccoon, and passed through forty feet of drift, below which was forty-four feet of

*[illegible]

a soft sandstone, probably to be referred to the Cretaceous. At the Brushy Fork mine the shaft is not deep, and the horizon probably represents that opened on Middle Raccoon river to the north.

The beds above the Lonsdale coal up to the base of the Missourian consist essentially of sandstone or sandy shale. As penetrated at the Lonsdale mine (Sec. 18, Penn township), there was a thickness of thirty feet of such shales between the coal and the lowest limestone ledge. There is some question, however, whether this limestone should not be included with the Des Moines rather than the Missourian. It is about twelve to fourteen inches in thickness, of granular texture, and carries small, smooth specimens of *Athyris subtilita*. As seen on Deer creek (Sw. of Nw. Sec. 17, Penn township) it is about ten feet below the fragmental limestone which it is proposed to take as the base of the Bethany. Between the two are sandy to argillaceous shales. The limestone is seen near the Driscoll mine, and at several points on Deer creek and South Raccoon, but is apparently not always present. In the boring at Stuart no trace of it seems to have been found. Below what may be taken as the base of the Missourian was about ninety-two feet of sandy shale, with some harder bands. This would seem to indicate the absence of the limestone in question and a thickening of the shale. In Madison county an arenaceous limestone is occasionally found at the indicated horizon. At Tileville it is twenty-five to thirty feet below the base of the Winterset, and rests upon about fifty feet of sandy shale. At other points similar relations obtain. In general they indicate a thickening of this upper shale member toward the south, and a dip of the beds in the same direction.

The strata found in Guthrie and neighboring counties below the base of the Missourian fall naturally into the four following groups.

1. Shales, variegated, but predominantly sandy, characteristically free from coal, with an occasional development of arenaceous limestone somewhat above the middle of the bed.

This formation corresponds in a general way with number 44 of St. John's middle coal measure section and includes numbers 1 to 3 of White's Winterset section.* It varies in thickness from forty to 100 feet, increasing to the south. In a general way it is probably the equivalent of the Pleasanton shales of Missouri and Kansas. The original northern boundary of this formation seems to have been not far from its present limits in Guthrie county, as it thins very rapidly from Stuart north.

2. Shales, sandstones, and limestones with three coal horizons. This formation includes numbers 26 to 43 of St. John's section and its character is sufficiently indicated by the sections already described. It is characterized by the great persistence of its individual members and is recognized through Guthrie and Dallas counties and in part in Madison county. It is probably the equivalent of the Appanoose formation† of southern Iowa and the Henrietta formation of Missouri.

3. Sandstones and sandy shales with Redfield coal at base, including numbers 19 to 25 of St. John's section. Seen in part at the Tann Mill exposure and well exposed in Dallas county. This member is probably not to be separated from number 4, though in the immediate region it is rather distinct.

4. Shales, sandstones and thicker coal seams characteristic of the greater portion of the Des Moines formation. Represented in the deeper borings of Guthrie county and exposed in the counties to the east; corresponding in general character and position with the Cherokee shales of Kansas.‡

These beds form a continuous series and are, so far as can be seen, conformable. In Appanoose county, however, there is a well marked conglomerate over the Appanoose formation.§ In Guthrie county one of the limestones of the second

* Geol. Iowa, vol. I, plate opp. p. 245. 1870.
† Iowa Geol. Surv., V, p. 378.
‡ Haworth: Univ. Geol. Surv, Kansas, I, 150-151. 1896.
§ Iowa Geol. Surv., V, 394-398.

member contains many rolled pebbles and other evidences of shore action, while the sandstone just below shows ripple marks. The sandstone found near Panora does not fit in with any portion of the section seen there. It is anomalous in character and is in places quite conglomeratic. There is some evidence of unconformity between it and the underlying beds. Nevertheless it contains plant remains which unmistakably ally it with the Des Moines. These facts all give evidence that throughout the later as well as the earlier portion of Des Moines time there were disturbances, and that local unconformities may be expected throughout the formation. The best exposure of disturbed strata may be seen at the Belle Valley mill exposure. Here about fifty feet of lower beds have been thrown up so that the strike is now Ne–Sw, with a dip of 45° to the southeast. They have been to some extent faulted, and after the upheaval were planed off so as to form an even surface over the top. Evidently the rocks formed then a flat-topped knob, as a later sandstone laid down over the top is also banked in against the side and with bedding planes dipping away from the upturned beds. This later sandstone is similar in character to that found at Panora. It carries the same plant remains and at the base includes fragments of the underlying rock. The disturbance evidently took place during the Des Moines. The beds thrown up belong to the Des Moines strata, though their exact place in the section cannot be given. They evidently do not belong with those seen in the neighborhood (see p. 437), but are lower and probably represent the upper portion of the Cherokee shales. If this be true a considerable amount of erosion took place before the deposition of the overlying sandstone; which accords well with the indications of the exposure itself. The beds thrown up are all as follows:

	FEET.	INCHES.
12. Limestone, impure, clayey, with *Productus muricatus*, *P. cora* and *P. nebrascensis*.	1	
11. Shale, drab, becoming coaly at top	4	
10. Limestone, similar to number 12	1	

		FEET.	INCHES.
9.	Shale, drab to green, clayey	5	
8.	Limestone, earthy, unfossiliferous		4
7.	Coal, impure	1	
6.	Shale, drab, clayey	12	
5.	Calcareous sandstone		8
4.	Shale, argillaceous, drab above to red below	10	
3.	Limestone, fine-grained, argillaceous, nonfossiliferous		6
2.	Shale, black, slightly bituminous	6	
1.	Shale, drab, argillaceous	4	6

The movement does not seem to have been sufficiently intense to have developed any secondary structure. The shales have cleavage planes parallel to original bedding and the jointing in the surrounding sandstone seems to have no relation to the upthrust. Numbers 7 and 8 have been faulted at one place, there being a throw of nearly a foot. The beds above and below are not affected. Numbers 11 and 12 appear only at the lower corner of the exposure and might be taken for a repetition by faulting of 9 and 10, if it were not for the well marked coaly character of the upper portion of number 11. In character and fauna number 12 resembles number 38 of the general section; but even after the upthrust it is below the level of that bed and the strata below are entirely out of harmony with anything seen elsewhere along the river.

MISSOURIAN FORMATION.

Above the Des Moines and covering the southeastern portion of the county is the Missourian formation. The only portion of this formation outcropping is the basal or Bethany limestone. This is shown along the lower portion of Beaver creek, Deer creek, Long Branch and South Raccoon river. The stone has not been quarried to any considerable extent, so that there are no extensive exposures. The rock, as usual, lies in ledges varying in thickness from six to twenty-four inches, which are separated by shaly argillaceous partings. A total thickness of fifty-five feet is indicated near the Lonsdale mine. This is near the edge, and probably does not rep-

resent the full thickness of the formation. The Easton well, at an altitude of about 1,200 feet, showed a thickness of 140 feet of drift below which was eighty feet of limestone. Since the base of the Earlham limestone in the Earlham quarries is at about 1,000 feet A. T. this would indicate that the strata here are practically horizontal and would agree with the results obtained by Norton from a general study of the artesian wells of the state. The limestone, where exposed, is quite fosiliferous, the forms present being those common to the limestone in other counties. The following is a list of fossils collected along Deer creek north of Stuart by Professor Calvin.

Lophophyllum proliferum.
Axophyllum rude.
Stems of *crinoidea.*
Archæocidaris, three species.
Fistulipora nodulifera.
Rhombopora lepidodendroides.
Orbiculoidea nitida.
Derbya crassa.
Derbya robusta M. & H.
Meekella striato-costata Cox.
Chonetes granulifera Owen.
Productus longispinus Sowerby.
P. costatus Sowerby.
P. nebrascensis Owen.
P. cora = *P. prattenianus.*
Spirifer cameratus Morton.
S. plano-convexus.
S. lineatus.
Athyris subtilita = *S. argentea* (Shepard) Keyes.
Hustedia mormoni Marcou.
Terebratula (Dielasma) *bovidens* Morton.
Cryptacanthia compacta W. & St. J.
Nucula ventricosa Hall.
Nuculana bellastriata Stevens.
Edmondia sp.
Aviculopecten sp.
Bellerophon percarinata.
Bellerophon sp.
Pleurotomaria sp.
Petrodus occidentalis

Along a small tributary of Deer creek, where most of these fossils were found (Sec. 19, Penn township), the following beds were made out.

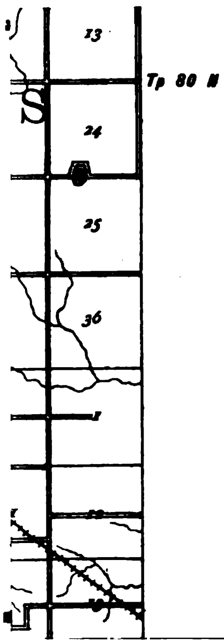
		FEET.
5.	Limestone, coarse, gray; with Fusalina similar to that occurring at Winterset	2
4.	Shales, only in part exposed	8
3.	Earlham limestone, ash gray, with conchoidal fracture, in layers two to ten inches thick, separated by shale partings	12
2.	Shale, gray, argillaceous, becoming bituminous and slaty at the top	10
1.	Limestone, fragmental, made up of irregular bits of lime rock filled in with calcareous clay. In places the rock can be picked to pieces with the fingers; elsewhere it hardens up into massive thick bedded (two feet) layers	10

The Fragmental limestone (number 1) rests on sandy shales which form the top of the Des Moines formation. The rock itself is very characteristic, and has been traced through Dallas and Madison counties. Besides its distinctive physical characteristics it carries a well marked fauna, of which the following forms were collected at this point.

Spirifer lineatus, very abundant, and especially characteristic of this horizon.
S. cameratus.
Athyris subtilita, common.
Hustedia mormoni, fairly common.
Productus longispinus.
Naticopsis altonensis.
Lophophyllum proliferum, common.
Orthis pecosi, very rare.
Bellerophon, *sp.*, rare.
Straparrollus, *sp.*, rare.
Archiocidaris, *sp.*, very rare.

In the shale partings of the Earlham limestone the following forms were collected.

Chonetes verneuiliana, common.
Spirifer cameratus.
Athyris subtilita, common.
Productus cora.
P. nebrascensis.



IOWA.

BY

H. F. BAIN

1897.

P. costatus.
Rhombopora lepidodendroides, common.
Meekella striata-costata.
Archiocidaris.

The character of the rock and the fossils found leave no doubt as to the correlation of these beds. The Winterset beds, occurring above the Earlham limestone, were not seen at this point, unless the Fusalina-bearing rock be taken as their representative. A rock similar in all respects occurs at Winterset and the bed found here is probably to be referred to that horizon rather than to the Fusalina limestone proper occurring farther west in Madison county. This is the more probable from the fact that the Winterset beds are present in the vicinity. It may be noted that the limestone found here shows each division in its normal thickness and character.

The Bethany limestone, using that term to cover the Fragmental, Earlham, Winterset and Fusalina limestones with intercalated beds, is made up of the four separate limestones just enumerated. Of these, the Fragmental and Earlham are well developed in Guthrie county. The Winterset, restricting that term to the beds quarried southwest of Winterset, is present, but not well shown. The Fusalina limestone seems to have been cut away.

The limestone found here outcrops throughout the southwestern portion of Dallas county to Earlham in Madison county. From this point it has been traced by Tilton to Winterset, where it is quite well exposed. At the latter point this layer of heavy limestone has been recognized as the base of the Missourian formation.* It represents the same horizon as the Bethany limestone of Missouri and the Erie limestone of Kansas, the connection between the Winterset and the Bethany limestone having been traced in the field.†

There has recently been some discussion as to which of the three terms, Winterset, Bethany or Bethany Falls as first used, or Erie has priority. The section at Winterset was

*Tilton: Iowa Geol. Surv., vol. III, p. 135. Des Moines, 1895.
†Iowa Geol. Surv., vol. VII, p. 23. 1897.

described by White in 1868* and again in more detail in 1870.† It was selected by him as typical for the upper coal measures and the fossils characteristic of it were specified. Tilton‡ later used the name carefully noting the position of the limestone at the base of the Missourian formation. The term Bethany Falls was used by Broadhead§ in describing the Missouri exposures. The equivalence of the Bethany Falls and Winterset limestone was recognized by Keyes‖ and has since been traced in the field. In Kansas the equivalent horizon was discussed by Haworth and Kirk¶ under the name of Erie, was later referred to by Haworth** as the Triple limestone and was finally given the name of Erie.†† The equivalence of the three formations was recognized by Keyes in 1895 and it was suggested‡‡ that the term Bethany be extended to cover the whole horizon. Later§§ the same author showed the term Erie to be pre-occupied and urged the priority of Bethany.

Broadhead's prior use of the term Bethany seems to entitle it to recognition, and it is proposed to use that term for the basal limestone of the Missourian formation. As has been suggested, this basal limestone includes four members, and for one of them the term Winterset is reserved. The various members of the Bethany have been recognized along Grand river in Decatur county, and at many intermediate points. In Union county there are higher, as yet unnamed beds.

The Guthrie county outcrops are the most northerly of the exposures of this limestone in the central portion of the state. The strike of the formation in Madison county is northwest, in Dallas the strike changes to west, and in Guthrie this strike is maintained to the point at which the lime-

* First and Second Ann. Rept. State Geologist, 71-72. Des Moines, 1868.

† Geol. Iowa, vol. I, pp. 245-250. Des Moines, 1870.

‡ Iowa Acad. Sci., vol. III, p. 144. 1895. Iowa Geol. Surv., III, 137. 1895

§ Trans. St. Louis Acad., vol. II, 311, 144. 1862. Mo. Geol. Surv., Iron Ore and Coal Fields, pt. ii, p. 77, et seq. 1873

‖ Mo. Geol. Surv., vol. IV, p. 83. Jefferson City, 1894.

¶ Kansas Univ. Quart., vol. II, p. 105. Lawrence, 1894.

** Ibid., vol. III, p. 275. 1895.

†† Univ. Geol. Surv. Kansas, vol. I, p. 154. 1896.

‡‡ Amer. Jour. Sci., (3) vol. L, p. 243. 1895.

§§ Ibid., (4) vol. II, pp. 221-235. 1896.

stone passes beneath the Cretaceous. It probably does not change between this point and the Missouri river. In drill holes and shafts along South Raccoon, Brushy Fork and Middle Raccoon there are no traces of the Missourian north of its present line of outcrop. In the western portion of the state the most northerly outcrops known are on the Boyer river in Harrison county,* almost due west of the Guthrie county outcrops, so that a line connecting the two points probably marks the present northern border of the formation.

It is probable that the Missourian originally extended out over the Des Moines. Its present outcrop is an accident of erosion rather than a function of original distribution. Within the area of the Missourian there are, in this county, no outcrops of strata higher than the Bethany limestone, so that only the basal portion is known to be present.

CRETACEOUS.

DAKOTA.

Above the coal measures, and covering the major portion of Guthrie county, is a series of sandstones, shales and conglomerates which belong to the Cretaceous. These beds are exposed along both branches of the Raccoon river, Brushy Fork, Beaver creek, Spring branch and many of the minor streams. They are separated from both the Carboniferous and the Pleistocene beds by unconformities.

Exposures of the Cretaceous are frequent along Middle Raccoon as far down as Clark's mine, about three miles northwest of Panora (Tp. 80 N., R. XXXI W., Sec. 24, Nw. qr., Se. ¼). Above the wagon bridge at this point and on the east side of the river is the following exposure.

		FEET.
4.	Drift	10
3.	Conglomerate, quartzite and cherty pebbles, with sandy matrix, only slightly consolidated	8
2.	Sandstone, soft, yellow, with a few scattered pebbles similar to those occurring in the conglomerate	20
1.	Shale, sandy, drab	4- 8

*White: Geol. Iowa, vol. II, p. 179.

The shale, which evidently belongs to the coal measures outcropping along the river, is separated from the sandstone by an obvious unconformity. The sandstone and the conglomerate belong together since they grade in places into each other, the pebbles becoming more abundant and the sand less, till the material is best called a coglomerate with sandy matrix rather than a sandstone with scattered pebbles. Traces of conglomerate may be seen near the mine, and pebbles from it are very common in the drift south and east of here. The pebbles are all water worn and thoroughly rounded. There are many bits of clear and colored quartz, chert and siliceous fragments of Devonian and Silurian fossils. Farther up the river the sandstone becomes more and more prominent. It is frequently exposed near Fanslers, and in the vicinity of Rocky Bluff (Tp. 81 N., R. XXXII W., Sec. 27, Ne. qr.) forms a constant bench in the hills at a height of seventy feet. It is soft, yellowish red, cross-bedded, and contains occasional pebbles such as mark the conglomerate. Opposite the mill it forms a sharp bluff, exposing seventy feet of thickness above the water's edge. A few miles beyond (Tp. 81 N., R. XXXII W., Sec. 20, Sw. qr., Sw. ¼) the sandstone forms a ridge between the river and a small stream flowing in from the southwest. It rises to the usual height and has two thin beds of very clear plastic blue clay interstratified with it. Still farther up the river (Tp. 81 N., R. XXXII W., Sec. 24, Ne. qr.) the clay is more prominent. St. John gives the following section at this point.*

		FEET.
7.	Very soft, light colored, irregularly laminated sandstone	35-40
6	Yellow clay, enclosing ferruginous, arenaceous bands	4
5.	Blue clay	5
4.	Soft red and yellow sand rock, with ferruginous nodules and bands, and thin layers of pebbles, with pebbles of silicified corals of Devonian and Silurian origin	20
3.	Ferruginous arenaceous layer containing isolated "pockets" of coal	2

*Op. cit., p. 100.

		FEET.
2.	Blue, arenaceous clays	17
1.	Light colored, incoherent sands, capped with deep red shaly ferruginous sandstone	10- 15

These beds rest unconformably upon the coal measure strata. The coal mentioned is doubtless an impure lignite and has not been observed in the course of the present work. The lower blue clay is not so clean or plastic as at the section observed farther down the river. There are outcrops of the sandstone and conglomerate in the vicinity, but upon the whole it does not seem that individual layers can be widely correlated. The sandstone is usually bright colored. It varies in induration, but is usually soft. At Guthrie Center it is so soft as to be excavated for building sand. In the pit of Mr. Samuel McLune, at three feet above the river, is a five foot bed of clean white sand, so loose as to be easily shoveled. Above this is twelve to fifteen feet of darker material, becoming harder at the top. It contains the quartz pebbles, such as are so characteristic of the formation. Still higher in the hill is the dark red sandstone, closely set with quartz and chert pebbles, such as is commonly shown in outcrops.

Across the river near the fair grounds an unusual amount of clay is shown in connection with the sandstone. The clay is about twenty feet thick, reddish below, but becoming white above, and rests on the sandstone. It contains some bands of sand and thin ferruginous streaks, and has a slight dip to the west.

Near Glendon the sandstone shows numerous outcrops. In a section already given it rests upon the coal measures at a height of twenty-five feet above the railway. In a neighboring cut the sandstone is exposed at much lower level with no evidence of disturbance, so that there is excellent proof of unconformity. At this point the stone contains plant remains, but the specimens are so imperfect as not to permit specific identification. In the judgment of Professors Calvin and Macbride, however, they represent Mesozoic forms.

The conglomerate is best exposed along Spring branch between Glendon and Menlo. It is so unconsolidated that it has been used by the Chicago, Rock Island & Pacific railway for ballast, and has been dug out by shovel and pick as ordinary gravel. It has here the usual constitution, with the marked prominence of quartz and chert pebbles. The material is thoroughly rounded and waterworn. Sand, or loosely cemented sandstone, forms the bottom of the pits and is in places interstratified with the gravel. The general appearance of the gravel is shown in figures 70 and 71.

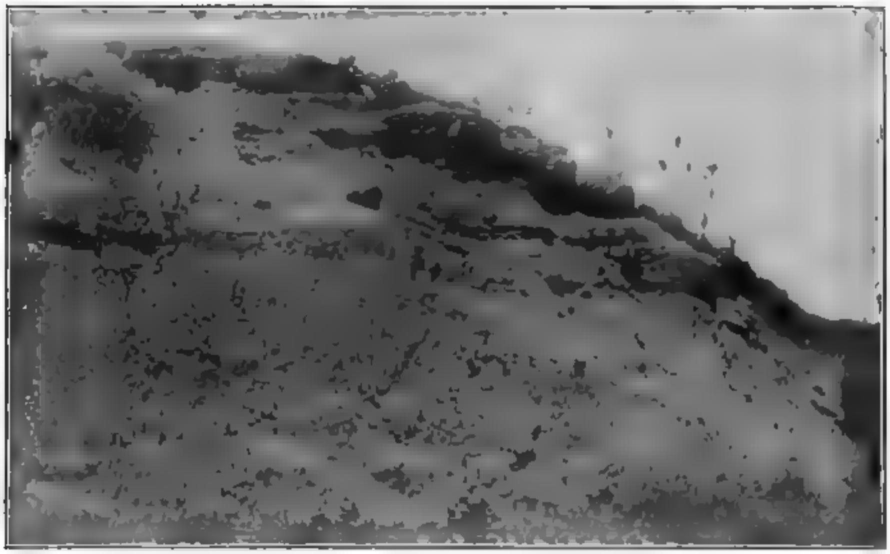


FIG. 70. Dakota conglomerate near Glendon East end of gravel pit.

The formation which is here referred to the Cretaceous will be seen to include three kinds of beds; sands or sandstones, clays or shales, and gravels or conglomerates. The clay or shale members are least widely spread. In addition to the occurrences already noted the only one of much importance is near the Anderson mine southeast of Guthrie Center where Cretaceous clays are found in connection with the sandstone. There are other occurrences in the southwestern portion of the county, but in general the Cretaceous of this

region carries very little argillaceous material. The sediments of which the formation was formed were mainly the result of mechanical disintegration.

The sandstones are widespread and are found outcropping throughout the area indicated on the map. They are lithologically similar to the sandstones of the coal measures, and perhaps could not be differentiated from the latter if it were not for the presence of the pebbles characteristic of the gravels. The lithological resemblance makes it easy to

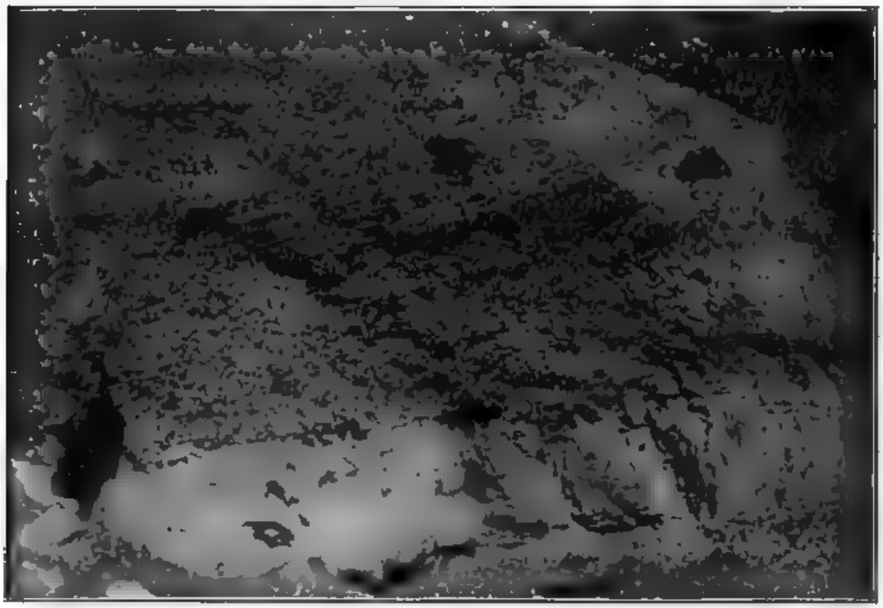


FIG 61. Dakota conglomerate near Glendon, Center of railway gravel pit.

assign the coal measures as the source of the sand of the Cretaceous. This is well in accord with the stratigraphy of the region. The gravel is perhaps the most interesting member of the Cretaceous. It is wholly unlike any other gravel or conglomerate in this portion of the state and cannot be confused with anything in the coal measures. In eastern Iowa, outliers have been noted by Norton* which carry chert and quartz pebbles, with occasional bits of red jasper and pink

*Norton: Iowa Geol. Surv., vol. III. p. 128.

quartz, and which are of Carboniferous age, but no such beds are known in the coal measures of central Iowa. In addition to the cherts and quartzes found in the Guthrie conglomerate or gravel are numerous silicified bits of fossils, the following being determined by Professor Calvin.

Cyathophyllum, sp.
Bryazoa; DEVONIAN?
Spirifer, cf. *S. eudora;* NIAGARA.
Favosites favosus, Goldf.; NIAGARA.
Streptelasma, sp
Favosites hisingeri, Ed & H. (*F. venustus* (Hall) Rom., *Astrocerium venustum* Hall); NIAGARA
Ptychophyllum expansum, Owen; NIAGARA
Streptelasma spongaxis, Rom.??; NIAGARA.
Zaphrentis stokesi, Ed. & H.; NIAGARA.
Favosites, cf. *F. hispidus*, Rom., NIAGARA.

The presence of these fossils derived from the older Paleozic of eastern Iowa indicates that before the conglomerate was formed eastern Iowa had been exposed to erosion for a very long time and apparently had been base-leveled. Only the cherts and siliceous fragments which were left practically untouched by solution remained. It should be noted furthermore that the conglomerate, though it is made up of very hard material only, and though it was manifestly formed after a long time interval of erosion, is not strictly a basal conglomerate. In every observed case it rests upon sands and finer material which are of the same age and do not belong to an earlier formation. The Cretaceous sea apparently crept in over a base leveled country. Mechanical agencies became supreme after a long period in which solution had been at work. The friable material of the coal measures was first broken up and redeposited as sand. It did not form a basal conglomerate, since it was too easily disintegrated to take conglomeratic form. When the sea laid under tribute the previously leached plains of the earlier paleozoic it found the surface covered with hard material already separated, and a conglomerate resulted. Conglomerates do not necessarily mean the

breaking up of rock, and great unconformities are by no means always marked by conglomerates. The latter are formed merely when the sea can get hold of suitable material, and that may be when it first invades a region or some little time after, as in this case.

The beds here referred to the Cretaceous are, as has been said, unconformable upon the coal measures and represent a later period of deposition. They are evidently much later than the paleozoics of eastern Iowa from which the chert nodules were derived. They were made by the sea creeping in over an apparently base-leveled surface.

The deposits found in Guthrie county represent shore deposits, but they do not represent the greatest eastern extent of the Cretaceous in Iowa, nor does the present line of outcrops represent exactly the present eastern limit of the formation. It is altogether probable that outliers will be found in this and the counties to the east. Dr. James Lonsdale reports an outlier in Jackson township (Tp. 79 N., R. XXX W., E. ½, Sec. 27). In wells in the northeastern portion of Guthrie it is usual to find sandstone below the drift. In many cases this is probably Cretaceous, especially since it seems frequently to be covered by gravels such as belong to that formation. The sandstone may, however, belong to the coal measures and the gravels may represent the drift, so that it is not possible accurately to discriminate the Cretaceous. Similar beds have been penetrated in certain wells in Dallas county and the peculiar gravel charateristic of the Cretaceous is abundant in the drift of that county. Possibly some of the gravel is *in situ*. Certainly much of it has been very little moved. Cretaceous fossils have frequently been found far to the east of the present outcrops. Keyes has found well preserved fossils in the drift at Des Moines.* White† has reported them from the drift of Howard, Black Hawk and Johnson counties, and Worthen‡ notes similar

*Proc. Iowa Acad. Sci., vol. I. pt. II, 1890-1891, p. 21. 1892.
†Proc. Am. As. Adv. Sci., vol. XXI, pp. 187-192. 1873.
‡Geol. Surv. Ill., vol. VIII, pp. 3-7. 1890.

occurrences in Iowa, Illinois and Missouri. N. H. Winchell has reported Cretaceous *in situ* as far east as Goodhue* and Dakota† counties in Minnesota. H. V. Winchell has found Cretaceous beds in the northeastern portion of the same state,‡ the beds being also described by Spurr.§

These various occurrences make it evident that the Cretaceous formerly extended much farther east. Lithologically similar deposits occur at points throughout Iowa, Illinois, Minnesota and Wisconsin. Some of these have been shown to be of Carboniferous age.‖ Others, including the Rockville conglomerate described by McGee,¶ have been referred to the Cretaceous. Still others have been considered to be Tertiary.**

It is certain that while some of these outliers may be correctly correlated with the Guthrie county beds others may be of later or earlier age. The sea advancing over the paleozoic rocks of the upper Mississippi valley after a period of base-leveling would be apt to build up the same sort of beds, regardless of the time of the invasion. In this case a correlation upon homogeny†† or community of genesis, would alone lead to unsatisfactory results. Fortunately there is better evidence of the age of the Guthrie county Cretaceous. While fossils are not abundant they have been found. St. John mentions‡‡ "impressions of linear leaves" derived from the sandstone on Beaver creek. The specimens collected in the course of the present work from the railway cut near Glendon have been already mentioned. Cretaceous invertebrate fossils have been from time to time found in the drift, but so far they have not been discovered *in situ*. Specimens of Callista, Cardium and Buccino-fusus, collected near

*Geol. Nat Hist., Surv. Minn., Final Rept., vol. II, pp. 44, 45. 1888.

†Ibid, 84.

‡Sixteenth Ann. Rept., Minnesota Geol. Nat. Hist. Surv., 395-478. 1888. Amer. Geol., XII, 220-223. 1893.

§Geol. Nat. Hist. Surv., Minnesota, Bul. X, pp. 80, 148-199. 1894.

‖Osborn: Proc. Iowa Acad. Sci., vol. I, pt. ii, 1890-1891, p. 115. 1892. Norton: Iowa Geol. Surv, vol. III, pp. 129-130. 1893.

¶Eleventh Ann. Rept., U. S. Geol. Surv., pt. i, pp. 304-308. 1891.

**Worthen: Geol. Surv. Ill vol. I, p. 330, 1866; Ibid, vol. IV, p. 91, 1890; vol. VIII, 3-7. 1890. Salisbury: Jour. Geol., vol. III, 655-667. Chicago, 1895.

††McGee: Am. Jour. Sci., (3), vol. XL, pp. 36-41. 1890.

‡‡Op. cit., p. 104.

Stuart by Mr. E. E. Hadley, are quite well preserved, and show portions of the matrix in which they were imbedded. This is a coarse-grained, friable sandstone, identical in character with that which occurs so abundantly in the Cretaceous of the vicinity.

The stratigraphical relations make it evident that the beds may not only be referred to the Cretaceous but more specifically to the Dakota. When first described by White* and St. John† they were referred to the Nishnabotna, which was considered to be the equivalent of a portion of the Dakota as defined by Meek and Hayden.‡ The typical Nishnabotna is exposed in Cass, Adams, and Montgomery counties,§ and is clearly the stratigraphic equivalent of the Guthrie county beds. At Lewis, in Cass county,‖ and at Red Oak, in Montgomery county,¶ plant remains have been found which Meek considered to be the same as species occurring in the "Lower Cretaceous of Nebraska," Dakota, as now known.

North of Guthrie county the Cretaceous crops out in Greene,** Carroll†† and Sac‡‡ counties. Near Auburn, in the latter county, it is found in connection with the chalk deposits,§§ as at Sioux City. The distribution, stratigraphical position, fauna and flora so far as known, and the lithological character of these various outcrops place them together and indicate that they are of Dakota age; that they represent the basal portion of the Cretaceous of the state. The upper beds found near Sioux City are not now present in the region though it is not improbable that they may at one time have been present. The long and vigorous erosion to which the region was subjected between the close of the Cretaceous and the beginning of the Pleistocene has cut away all but a remnant of the formation.

*White: Geol. Iowa, vol. I, p. 299. 1870.
†St. John: Idem, vol. II, p. 99.
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††Idem: pp. 143-145.
‡‡Lonsdale: Proc. Iowa Acad. Sci., II, 1894.
§§Calvin: Iowa Geol. Surv., III, p. 226. 173. 1895.

quartz, and which are of Carboniferous age, but no such beds are known in the coal measures of central Iowa. In addition to the cherts and quartzes found in the Guthrie conglomerate or gravel are numerous silicified bits of fossils, the following being determined by Professor Calvin.

Cyathophyllum, sp.
Bryazoa; DEVONIAN?
Spirifer, cf. *S. eudora;* NIAGARA.
Favosites favosus, Goldf.; NIAGARA.
Streptelasma, sp
Favosites hisingeri, Ed & H. (*F. venustus* (Hall) Rom., *Astrocerium venustum* Hall); NIAGARA
Ptychophyllum expansum, Owen; NIAGARA
Streptelasma spongaxis, Rom.??; NIAGARA.
Zaphrentis stokesi, Ed. & H.; NIAGARA.
Favosites, cf. *F. hispidus*, Rom., NIAGARA.

The presence of these fossils derived from the older Paleozic of eastern Iowa indicates that before the conglomerate was formed eastern Iowa had been exposed to erosion for a very long time and apparently had been base-leveled. Only the cherts and siliceous fragments which were left practically untouched by solution remained. It should be noted furthermore that the conglomerate, though it is made up of very hard material only, and though it was manifestly formed after a long time interval of erosion, is not strictly a basal conglomerate. In every observed case it rests upon sands and finer material which are of the same age and do not belong to an earlier formation. The Cretaceous sea apparently crept in over a base leveled country. Mechanical agencies became supreme after a long period in which solution had been at work. The friable material of the coal measures was first broken up and redeposited as sand. It did not form a basal conglomerate, since it was too easily disintegrated to take conglomeratic form. When the sea laid under tribute the previously leached plains of the earlier paleozoic it found the surface covered with hard material already separated, and a conglomerate resulted. Conglomerates do not necessarily mean the

breaking up of rock, and great unconformities are by no means always marked by conglomerates. The latter are formed merely when the sea can get hold of suitable material, and that may be when it first invades a region or some little time after, as in this case.

The beds here referred to the Cretaceous are, as has been said, unconformable upon the coal measures and represent a later period of deposition. They are evidently much later than the paleozoics of eastern Iowa from which the chert nodules were derived. They were made by the sea creeping in over an apparently base-leveled surface.

The deposits found in Guthrie county represent shore deposits, but they do not represent the greatest eastern extent of the Cretaceous in Iowa, nor does the present line of outcrops represent exactly the present eastern limit of the formation. It is altogether probable that outliers will be found in this and the counties to the east. Dr. James Lonsdale reports an outlier in Jackson township (Tp. 79 N., R. XXX W., E. ½, Sec. 27). In wells in the northeastern portion of Guthrie it is usual to find sandstone below the drift. In many cases this is probably Cretaceous, especially since it seems frequently to be covered by gravels such as belong to that formation. The sandstone may, however, belong to the coal measures and the gravels may represent the drift, so that it is not possible accurately to discriminate the Cretaceous. Similar beds have been penetrated in certain wells in Dallas county and the peculiar gravel charateristic of the Cretaceous is abundant in the drift of that county. Possibly some of the gravel is *in situ*. Certainly much of it has been very little moved. Cretaceous fossils have frequently been found far to the east of the present outcrops. Keyes has found well preserved fossils in the drift at Des Moines.* White† has reported them from the drift of Howard, Black Hawk and Johnson counties, and Worthen‡ notes similar

*Proc. Iowa Acad. Sci., vol. I. pt. II, 1890-1891, p. 21. 1892.
†Proc. Am. As. Adv. Sci., vol. XXI, pp. 187-192. 1873.
‡Geol. Surv. Ill., vol. VIII, pp. 3-7. 1890.

occurrences in Iowa, Illinois and Missouri. N. H. Winchell has reported Cretaceous *in situ* as far east as Goodhue* and Dakota† counties in Minnesota. H. V. Winchell has found Cretaceous beds in the northeastern portion of the same state,‡ the beds being also described by Spurr.§

These various occurrences make it evident that the Cretaceous formerly extended much farther east. Lithologically [illegible] deposits occur at points throughout Iowa, Illinois, [illegible] and Wisconsin. Some of these have been shown to [illegible] age.|| Others, including the Rockville [illegible] described by McGee,¶ have been referred to the [illegible] others have been considered to be Tertiary.** [illegible] that while some of these outliers may be correlated with the Guthrie county beds others may be [illegible] age. The sea advancing over the paleozoic [illegible] Mississippi valley after a period of base-[illegible] be apt to build up the same sort of beds, [illegible] of the invasion. In this case a correla-[illegible] or community of genesis, would alone [illegible] results. Fortunately there is bet-[illegible] age of the Guthrie county Cretaceous. [illegible] abundant they have been found. St. [illegible] impressions of linear leaves" derived [illegible] Beaver creek. The specimens col-[illegible] present work from the railway cut [illegible] already mentioned. Cretaceous [illegible] from time to time found in the [illegible] not been discovered *in situ*. Speci-[illegible] and Buccino-fusus, collected near

[illegible] pp. 44, 45. 1888.

[illegible] 1888. Amer. Geol., XII,

[illegible] 1894.

[illegible] 1892. Norton: Iowa Geol.

[illegible] 1892.

[illegible] vol. VIII, 3-7, 1889.

[illegible]

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‡‡Lonsdale: Proc. Iowa Acad. Sci., II, 1894.
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PLEISTOCENE.

GENERAL RELATIONS.

Guthrie county lies on the southwestern border of the Des Moines lobe and affords an opportunity for studying the relations obtaining between the Wisconsin and the underlying drifts. The two formations present may be studied not only as superimposed but as deployed. The contrasts between the drift within and without the Des Moines lobe are well displayed, and differences which might fail of recognition under one set of conditions are obvious under the other. The region is as a result an exceptionally interesting one to all students of glacial geology. The interesting topographic contrasts have already been suggested. It remains to study more in detail the formations themselves.

KANSAN DRIFT.

The outlying drift sheet is that known as the Kansan drift. The Iowan drift does not appear upon the southern and southwestern borders of the Des Moines lobe. The drift present agrees in character with that which has been called Kansan in other reports of the Survey.* It has the same general constitution, being fundamentally a blue bowlder clay weathered above into a yellow, which in turn is usually a deep reddish brown at the surface. It contains the same sorts of pebbles, an examination near the Driscoll mine showing quartzite probably from the Sioux formation, sandstone from the Cretaceous, shale and limestone from the coal measures, light gray granites, pink quartz, porphyry, greenstone, vein quartz and other varieties of rock from extra-limital sources.

There is the usual large amount of local material, and large numbers of greenstones. The granitic bowlders are badly rotted and easily broken to pieces. The upper surface of the drift shows marked ferrugination and leaching. The drift has all the characteristics of an old drift long exposed to

*Norton: Iowa Geol. Surv., vol. IV, p. 169. 1895. Bain: Ibid, vol. V, p. 153. 1896. Beyer: Ibid, vol. V, p. 203. 1896. Calvin: Ibid, vol. V, p. 63-65. 1896.

weathering agencies *in situ*. As has already been seen, the topography is suggestive of the same history. The Iowan drift of northeastern Iowa is thinner, of different color—a light yellow—carries many large surface bowlders, shows many fresh cobbles, and only a few that are badly decomposed. It has a less percentage of local material and a higher percentage of gray granite, and shows almost no leaching or ferrugination. Upon these differences alone there would be ground for separating the two.

The topography gives further warrant for a separation. The topography of both areas is a river erosion topography, and the drainage is complete. The Kansan topography has, however, much greater relief than the Iowan. The latter is marked by a series of wide shallow river valleys having no marked river trenches. The marked, though not easily expressed contrast between the typical river valley of the Iowan drift area and that of the Kansan, affords yet another reason for distinguishing between the outlying drift of Guthrie county and the Iowan. Aside from these differences is the fact that the Kansan, as developed in Guthrie, may be traced around the southern end of the Des Moines lobe, being characteristically developed in Dallas, Polk and Jasper counties, into Marshall, where it is known to pass beneath the Iowan. It may also be traced more to the southward, as far east as Johnson and Cedar counties, where the same relationship holds true. The outlying drift of Guthrie county is not then the next drift sheet in point of age preceding the Wisconsin; but is still older. There is here an unconformity and overlap as real as any shown by the indurated formations.

That there may be a still older drift sheet present seems probable from the phenomena observed in other counties. At Afton in Union county, at Harvey in Marion, at Hastie in Polk and at many other points, the Kansan drift is known to overlie a still older sheet of till. In Guthrie county there is a certain amount of evidence which points in the same direction. At Stuart there is a bed of fine sand lying ninety feet

below the upland on which the station is built and outcropping in some of the neighboring ravines. This bed is ten to fourteen feet thick and is made up of thoroughly rounded particles 1 to 2 mm. in diameter, consisting mainly of quartz and feldspar with occasional bits of some ferro-magnesian constituent. The bed seems to occupy a constant horizon and is the source of the local water supply. Below it is reported a fine pebbleless blue clay with lime nodules but no pebbles, and said to be fossiliferous. It is not now exposed, but was at one time tested for brick making and at that time the lime content was found to be high. The description fits well a buried loess or at least a lake deposit. Such a deposit might of course have been formed at some stage in the retreat or advance of the Kansan ice, but it might also be formed in inter-glacial time and, particularly if the clay be a loess, falls in nicely with the evidence derived from the surrounding region and pointing to a widespread pre-Kansan drift. In the recent boring at Stuart 158 feet of bowlder clay was found below the buried sand beds. This lower bowlder clay here evidently occupies a buried channel cut almost through the Bethany limestone.

At the Belle Valley mill exposure there is, over the upper sandstone, a bed of coarse cross-bedded sandy conglomerate eight to ten feet thick. It is made up almost wholly of material derived from the Dakota gravel but includes also some greenstones, granite and glacial material. It is covered by three or four feet of coarse sand running up into a sandy loess-like material. The deposit is well down in the valley and may be considered to be post-Kansan. Probably it is also pre-Iowan and hence the equivalent of the Buchanan gravels of eastern Iowa.

The Kansan drift does not outcrop over large surface areas within this county since it is quite generally covered either by alluvium or by loess. It is found over limited areas on the high divides and quite generally along the stream ways. It may usually be seen in road cuttings on either side of the

ravines. As has already been indicated, the valleys are in the main earlier than the loess. The latter is found not only on the divides but runs down into the valleys so that frequently the drift is not exposed at all. The side ravines usually expose the drift, however, and it is not infrequently shown along the main streams since the pre-loessial contours seem on the whole to have been sharper than the post-loessial. The result is that any side wash has a tendency to reveal a line of drift, just as the indurated rocks because of their superior hardness form shoulders along the sloping valley sides.

IOWAN LOESS.

The loess present is of the usual character, being a fine, pebbleless, buff, silt-like material. It was described in the earlier reports as the "bluff deposit" and its presence east of the Missouri divide was recognized. It is here referred to as the Iowan loess, since it is believed to be the equivalent in this region of the Iowan drift farther north and now in part buried under the Wisconsin drift. It is believed that loess of widely different ages occurs in the Mississippi valley and probably in Iowa, and the qualifying term is added for the purpose of definitely fixing the age of this particular loess. The basis of the correlation is the fact that loess, apparently the same, may be traced around the southern limit of the Wisconsin to Marshall county where it comes into contact with the Iowan. It follows the border of the latter southeast, never lapping very far up on the drift, to Johnson county. Here its definite relationship to the Iowan drift is excellently shown.* Furthermore, the Iowan ice sheet, as shown by its border, probably marked a period of low level and clogged drainage such as is indicated by the relations of the loess in Guthrie county to the pre-existing river valleys. This period was between the Kansan and the Wisconsin as was also the period of loess deposition in this region, as is shown by the fact that the loess covers the Kansan and passes

Calvin: Geology of Johnson county, Iowa Geol. Surv., vol. VII, pp. 88-89. 1897.

beneath the Wisconsin. It was separated by a considerable interval from the Kansan, as is proven by the large amount of erosion to which the latter was subjected before the loess was laid down. That it passes beneath the Wisconsin may be seen upon the hillsides west of Panora where the loess is covered by the kame gravels of the Wisconsin. The fact is also indicated by numerous wells back some distance from the drift border, and by ravines and stream cuttings all along the margin. It is furthermore well in accord with the facts observed in other counties.*

Upham† has suggested that the presence of the loess in Guthrie, Carroll, Sac and Buena Vista counties immediately west of the moraine and the fact observed by him that in places the loess rises fifty feet above the drift hills, proves the contemporaneity of the loess and moraine. It does not seem that this interpretation is necessary or indeed well in accord with the facts. If the explanation offered be true it would be expected that the loess should be found along the eastern front of the moraine as well as its southern and western. That it does not occur in this position is shown by Calvin in his report on Cerro Gordo county.‡ The loess is well developed outside the Des Moines lobe, where the latter has overlapped the Iowan, but not so far as now known, elsewhere. Again it should not be forgotten that the Wisconsin drift is persistently fringed by gravels and similar deposits indicative of free drainage, while the loess is indicative of conditions under which the water could not, or at least did not, carry anything but the finest material. The two deposits are mutually antagonistic. A drift sheet which is constantly fringed by gravel is to be differentiated from one constantly fringed by loess. The two must have required different conditions. The general altitude of the land in one case was higher than in the other. This is not of course to be interpreted as meaning that local exceptions may not occur, but applies to cases

*See Geology of Polk County, Iowa Geol. Surv., vol VII, pp. 340-342. 1897.
†Geol. Nat. Hist. Surv., Minn., 1880, p. 338.
‡Iowa Geol. Surv., vol. VII, pp. 171-176. 1897.

where the conditions along an entire drift border are taken into account.

In the case in hand there is the additional fact that the loess passes directly under the Wisconsin drift wherever its relations have been made out. It is then older, and if difference in general erosion be any guide it is considerably more ancient than the Wisconsin drift. In Guthrie county no cases have been observed in which the loess stands higher than the Wisconsin. Such phenomena would not necessarily require the ice as a retaining wall. The loess covers the Mississippi-Missouri divide. The land rises from the east to the divide. This was apparently true before the Wisconsin ice invaded the region, so that the land west of the moraine would be expected to be higher, and where the moraine approaches the divide running parallel to it the difference might be locally great. This would be also true if the rise to the west be a function of recent elevation for which belief there is some evidence.

With regard to the length of time between the loess and the Wisconsin it may be said that, assuming the relative freedom of the drainage to be a function of the elevation of the region, an assumption well in accord with known facts and principles, the change in the general altitude of the land between the deposition of the loess and the Wisconsin is significant, and the time interval was probably considerable since epirogenic movements are not rapid.

The loess then was deposited at a time between the Kansan and the Wisconsin, and separated from each by a considerable interval. Conditions favorable to loess deposition prevailed when the Iowan ice occupied eastern Iowa, and this time accords well with that required by the facts in the case, so the loess of Guthrie county is referred to the Iowan.

In the northwest portion of the state there is a drift which is older than the Wisconsin and younger than the Kansan. In constitution, position and topographic development it resembles the Iowan of eastern Iowa, and it has been provisionally correlated* with that formation. There are many

*Iowa Geol. Surv., vol. VII, p 20. 1897.

reasons in support of the view that this correlation is correct, and so the headwaters of the pre-loessial streams of Guthrie county were doubtless crossed by the Iowan ice; and in a period of general low level with greatly expanded rivers the conditions for the distribution of the loess over the territory in question would obtain.

The relationships of the loess found here to the loess of the Missouri valley are perhaps not certainly known. White and St. John* considered the two to be the same, and nothing to negative this opinion has come out in the present study, though the investigation of that phase of the problem is not yet so complete as is desirable.

WISCONSIN DRIFT.

The drift covering the northeastern portion of the county is, at the surface, light buff in color, it contains fresh pebbles, is marked by surface bowlders, and is free from a loess covering. It contains relatively little material of local origin, and much which has been transported. The large limestone masses found north of the Raccoon river near Rocky Bluff, and probably derived from near Mankato, Minnesota, are conspicuous examples of transported blocks. Occasionally the Wisconsin has incorporated not only pebbles from the lower till but blocks of the clay itself. Some distance southeast of Panora (Tp. 79 N., R. XXX W., Sec. 15, Se. qr.) in a road cut at the east end of a bridge over Middle Raccoon, this feature is excellently shown. The Wisconsin drift is here a gray to buff clay quite full of small pebbles. In it are some large patches of older till. Some of these included patches are as much as two feet in diameter. The older material is sandier and contains more Cretaceous material and is much more highly colored. The newer drift shows foliation around these inclusions.

The most distinctive feature of the Wisconsin is perhaps its topography which has already been described. The drift

*Geol. Iowa, vol. II, p. 97. 1870.

border is also highly characteristic. At certain points there is a well-developed moraine. This is best seen not far northwest of Fanslers (Tp. 81 N., R. XXXI W., Sec. 28, Sw. qr.). The general upland here is about 130 feet above the river. It is flat and covered by a thin sheet of Kansan drift over which the loess is spread. Rising abruptly from this plain is the moraine which attains an elevation of fifty feet. It is a ridge of markedly rough topography and is covered by large surface bowlders. Inside the moraine the characteristic saucer topography is developed, and the large bowlders, while frequent, are rarer than along the moraine.

Along other portions of the border there is no trace of a moraine, but instead the drift becomes thinner and thinner till it fades out altogether. Along still other parts, notably at Rocky Bluffs (Tp. 81 N., R. XXXII W., Sec. 22, Se. qr.), and along the lower portion of the Middle Raccoon valley, the ice pushed down into the valley and occupied one side of it. At only one point does it seem that it may have crossed. Opposite Panora, on the main Guthrie Center road (Tp. 80 N., R. XXX W., Sec. 31, Sw. qr.), water-laid gravels of kame-like character are found well toward the top of the hill distinctly above the loess. No till has been found with them, but the presence of the gravels far above the usual gravel terrace, and the kame-like form seems to suggest a temporary crossing of the ice. The gravels occur along the hillsides in a small amphitheatre drained by the stream entering the river from the west. They are more or less perfectly shown at several points and at one or two take an imperfect kame form with a general northwest-southeast direction of axis.

Just south of Panora, gravels are developed at lower levels and show a tendency toward the kame form of aggregation. The gravel terrace which lies at a still lower horizon is excellently shown in the same vicinity.

South of Bayard, and again from Panora southeast into Dallas county, there is lower land inside the drift border than along it. The accumulation along the edge does not, however,

seem to be morainic, since it is often not a thickening of Wisconsin drift, but is due in part to rock and in part to a special accumulation of older drift. This appearance is often confusing but the phenomenon is not strictly morainic. It seems rather to be the result of stream rearrangements. South of Bayard it seems to indicate that Willow creek was formerly the major stream.

Overwash plains have not been found in the county. Kames, as already noted, occur near Panora, though they are not so well developed nor so characteristic as the kame at High Bridge in Polk county.

There is a well marked gravelly terrace along the Middle Raccoon river. It rises usually twenty-five to thirty feet above the river, and may be seen at Rocky Bluff very sharply defined, near Fansler, in the vicinity of Clark's mine (Tp. 80 N., R. XXXI W., Sec. 24, Ne. qr.), and near Panora. It is constant for the whole river valley, but is conspicuous at the points named. At Rocky Bluff the terrace forms a triangular strip rising twenty-five feet above the river. At the Clark mine the terrace shows on the west side of the river, being a quarter of a mile wide and rising twenty feet above the bottom land. The material of which the terrace is composed is a moderately coarse water-laid gravel with more or less coarse sand. It contains a large amount of material evidently derived from the Cretaceous gravel beds. It does not show a close connection with the character of the underlying strata from point to point as does the till, particularly the older or Kansan till.

There is a well marked forest bed which is frequently encountered in wells in the northeastern part of the county, particularly near the edge of the Wisconsin drift. North of Yale on the Eastwood farm (Tp. 81 N., R. XXX W., Sec. 28, Sw. qr.) the section showed the following beds, the thickness being given only approximately:

		Feet.
6.	Yellow clay	10
5.	Blue clay	30
4.	Red clay	3
3.	Forest bed	2
2.	Blue and red clay	5
1.	Sand, clear white	10

In many of the wells of the vicinity the forest bed is not reported, since the water and gas for which the wells were put down are found over it. The country is not cut by drainage lines so that there are not many opportunities for examining sections and none are known which show the forest bed distinctly.

ALLUVIUM.

The river valleys of the extra-Wisconsin region have usually well marked alluvial bottom lands. The major development of the alluvium is shown upon the accompanying map. It is impossible to map the smaller areas without the aid of a topographic base map. Along the smaller streams the alluvium grades so imperceptibly into the loess and the hillside-wash from it that no line between the two can be drawn. The alluvial areas as mapped include the terrace along Middle Raccoon, since the two formations are not readily separated upon a map of this scale.

ECONOMIC PRODUCTS.

Coal.

The coal mined in Guthrie county comes from a number of different horizons. That worked at the Greenbriar mine in the northeastern portion of the county probably represents the lowest horizon now worked. Along Middle Raccoon from Panora north and west and on Brushy Fork are the two horizons, corresponding to numbers 37 and 33 of the general section, which have been opened up. Below number 33 is the coal found at the Thomas mine but not as yet encountered elsewhere. Southeast of Panora and west of Linden coal is taken from a thin bed near the surface which seems to

represent the Marshall coal, though this is not wholly free from doubt.

The Lonsdale coal, which has been mined at numerous points along Deer creek, is the highest coal mined in the county. It occurs in two and occasionally in three benches, and while thin, is a good persistent horizon which belongs to the upper division of the Des Moines beds. Two other seams of lesser importance outcrop in the vicinity, as will be seen from the general section. About 100 feet below the Lonsdale coal is the seam formerly worked at Glendon and now opened up at the Anderson mine. It is a clean, brittle coal with good roof and bottom and easily worked with the pick. It probably extends over a considerable territory in the vicinity mentioned.

Deeper coal seams have been encountered at several points but have not been opened up. In the northeastern townships the red and blue shales of the Des Moines formation are frequently encountered below the drift, which is usually 100 to 200 feet thick. In the Sutherland well (Tp. 80 N., R. XX W., Sec. 12, Se. Se.) a six-foot bed of coal is reported at 240 feet, with a second vein at 300 feet. Two seams at about the same depth were found at Dale City. The latter well, while located further down the slight dip, was begun on much lower ground. The Easton well, probably about twenty feet above Stuart showed coal at 248 and 428 feet, the seams being said to be four feet thick. This is a churn drill record of a well put down for water and hence is not of the highest value. In a well near De Soto the following seams were encountered:

DEPTH—FEET.	THICKNESS—FEET.
98	1
239	2
253	1½
350	3

At Van Meter coal seams are present at 574 and 564 A. T., at Commerce the bed worked lies at 717 A. T. and lower beds

are known to be present, and at Des Moines the principal workable horizons are usually found at 779, 705 and 635 A. T. These facts indicate that up to the outcrop of the Bethany limestone and for some distance at least beyond, the Des Moines is a coal-bearing formation. In the Stuart boring, sixteen inches of coal, divided by 11 inches of black slate, was found at a depth of about 290 feet, and a second seam 4 inches thick at 453 feet.

The complete record of the Stuart boring upon the Savage & Dosh farm, kindly furnished to the Survey by the Stuart Prospecting Co., is given below.

		FEET.	INCHES.
40.	Drift	4	
39.	Sand, water vein	4	
38.	Drift, water vein	145	9
37.	Sand	6	
36.	Drift	16	
35.	Sand, water vein	3	9
34.	Limestone		3
33.	Sand shale light, pyrite bands	92	
32.	Clay shale, light	3	
31.	Limestone, fossiliferous		8
30.	Shale, blue		10
29.	Limestone, fossiliferous	1	2
28.	Shale, blue	5	
27.	Limestone		8
26.	Shale, black	1	2
25.	Coal		6
24.	Shale, bituminous		11
23.	Coal		10
22.	Shale, light	3	
21.	Sandstone	8	
20.	Shale, blue, red and brown	31	
19.	Clay shale, light	5	10
18.	Black shale	4	
17.	Rock, gray		7
16.	Black shale	2	8
15.	White shale	6	
14.	Black shale	2	
13.	Blue clay shale	3	
12.	White clay shale	4	
11.	Blue sand shale	6	
10.	Red clay to brown clay	35	9

		FEET.	INCHES.
9.	Gray sand shale	4	
8.	Brown clay shale to red and blue clay shale	14	
7.	Blue clay shale	3	
6.	Black shale	1	4
5.	Coal		4
4.	Blue clay shale	1	
3.	Blue clay shale	10	
2.	Blue sand shale with water vein	3	
1.	Limestone, blue	1	
	Total	46	4

The mines of the county are drifts or shallow shafts. They are worked for local trade only and are operated on small capital. They rarely include more than a few acres and most of them change hands frequently. The equipment is in most cases rather crude, though serviceable and usually all that is warranted by the thin seams and the merely local trade. The plant at the [illegible] mine includes a steam hoist, but the remainder of the mines are worked by horse power gins. Only a few of the mines work all the year. Many are closed during the summer and they employ only one or two men. A number of new drifts are made each fall and deserted in the spring. In [illegible] instances the mining location is [illegible] is evanescent. For these reasons it was impossible to get but little information about some of the mines and in most cases very little could be learned. The list given below is not complete, but it includes all mines operated during the season of [illegible], with notes upon certain ones which, because of their location, are important as [illegible].

With regard to the future of the mining industry of the county it may be said that the prospects are encouraging. There is a considerable amount of coal already in sight. The seams are thin but the quality is fair and the quantity ample for local use. The lower and usually more productive portion of the formation is concealed by drift, and has never been explored. There can be no doubt that it contains thick coal seams which will in time be opened up. This work will require

larger capital than has yet been employed in the mining industry of the county, but it cannot be doubted that in time Guthrie county will prove to be a largely productive field. The expense will necessarily be somewhat heavy, as the drill holes may have to be carried as far as the Saint Louis limestone, and they must be numerous since there are no surface indications of value. For obvious reasons the area over which the Des Moines crops out offers the best inducements, though it is not unlikely that coal may be found under the other formations.

The Greenbriar Coal Co. operates a shaft located on Snake creek, a tributary of the Raccoon, about three miles northeast of Herndon, and near Jamaica. (Tp. 81 N., R. XXX W., Sec. 1, Ne. qr., Nw. $\frac{1}{4}$.) The mine has been operated for eight years. The shaft is sixty-eight feet deep, and the coal seam averages two feet four inches in thickness. It is covered by forty-seven feet of black slate. A portion of the fire clay below the coal is lifted to make entry room. A short distance east of here, at Dawson, there is an important mining industry, three seams being known, twenty-two inches at sixty feet, a three-foot vein at a depth of 115 feet, and a three and one-half to four foot vein at 165 feet. At Angus, still further to the east, deep mining has been carried on for some years.

Southwest of Linden (Tp. 79 N., R. XXX W., Sec. 36, Ne. qr.) a seventeen-inch seam has been worked at several points along the Raccoon. New mines have been opened from time to time, the Stapes and the Keeler being perhaps best known.

Half way between the Linden and the Panora mines is a small group, among which may be mentioned the Burgess, Fisher and Dygert mines (Tp. 79 N., R. XXX W., Secs. 16 and 21). The section at this point has already been given. At the Burgess mine a twenty-inch seam is reached by a shaft at a depth of fifty-four feet. A lower vein is said to occur.

Near Panora mining has been carried on for many years, the coal occurring along three horizons, as already noted. The section at the Reese mine is representative. Within the

past year a new shaft was put down by Mr. Reese. Near it on the east side of the road is the mine of Walker Emery, which was also opened in 1896. The White Ash mine is located on the west side of the river just north of town (Tp. 80 N., R. XXX W., Sec. 31, Nw. qr., Se. ¼). It is inadvertently omitted from the map. Still farther north (Tp. 80 N., R. XXXI W., Sec. 25, Se. qr.) coal has been mined at the Harris mine, the bed being twenty inches thick and reached by a shaft twenty feet deep. On the opposite, north side of the river (Sec. 24, Nw. qr.), is the Clark mine, a new shaft with well-built top works.

Fanslers has long been known as a mining locality. At present there are eight mines in operation, all gin shafts, reaching the same coal horizon. The Hughes mine (Sec. 9, Se. Se.) is eighty feet deep, the Thomas (Sec. 9, Sw. qr., Se. ¼) and the Butler (Sec. 9, Nw. qr., Sw. ¼) are of the same depth. The Renslow (Sec. 4, Sw. Sw.) is sixty feet, the Merchants (Sec. 4, Sw. qr., Ne. ¼) is 111. Near the latter mine is the Winter mine (Sec. 4, Nw. qr., Sw. ¼). About a mile and a half west are the Scott mine, at which, as has been said, two seams are present (Tp. 81 N., R. XXXI W., Sec. 31, Se. qr., Sw. ¼), and that owned by Mr. J. Thomas (Tp. 80 N., R. XXXI W., Sec. 6, Ne. qr., Nw. ¼). Numerous other mines have been opened up from time to time, but are now abandoned.

South of Bayard coal has been taken out at several points for many years. The Wales mine (Tp. 81 N., R. XXXII W., Sec. 32) and the Perkins (Sec. 29) are drifts. The Brushy Fork mine (Tp. 80 N., R. XXXII W., Sec. 5, Sw. Sw.) and the Burroughs, formerly the Hughes & Clark mines (Tp. 81 N., R. XXXIII W., Sec. 24), are shafts. The latter, omitted from the map by mistake, have been in operation for seven years, though new shafts have been sunk from time to time.

Near Guthrie Center the only coal found is at the Anderson mine (Tp. 79 N., R. XXXI W., Sec. 17, Se. qr.) opened this year. Coal was formerly worked on Beaver creek west of Glendon both by drift and shaft and a thin seam was at one

time worked by means of a drift northwest of Menlo (Tp. 78 N., R. XXXI W., Sec. 16). North of Stuart coal has been mined at several points along Deer creek and other tributaries of the Raccoon river. In the summer of 1896 the Driscoll (Tp. 78 N., R. XXXI W., Sec. 12, Sw. Sw.) and the Lonsdale (Tp. 78 N., R. XXX W., Sec. 18, Sw. Sw.) were the only mines open. Both were shafts operated, as usual, with gins and supply an important local trade. The Lamb and the Suggert & Saint mines were located in this district. The Muldoon mine (Tp. 78 N., R. XXX W., Sec. 12, Sw. Sw.) is located on Hog branch. All these mines take coal from the Lonsdale vein, which has also been from time to time opened up at many other points along Deer creek and the South Raccoon.

Clays.

The material available in Guthrie county for manufacture into clay goods is abundant. The Des Moines, the Cretaceous, the loess and the alluvium are all capable of furnishing material suitable for such work. The heavy shales especially desirable for the manufacture of vitrified brick and sewer pipe, and excellent for many other purpoes, must be obtained largely from the Des Moines beds. As has already been seen this formation is very generally made up of shales of great variety. It is now being used at a number of points, but its capabilities are by no means exhausted. Pottery, fancy face brick, and numerous other grades of goods may easily be made from it. The happy combination in the same formation of clay of wide variety and coal for fuel affords opportunities that must, in the future, commend themselves more generally than has yet been the case, to men of means and far-sighted business capacity.

The Cretaceous yields comparatively little clay, since arenaceous material predominates in the formation. Near the Anderson mine is a deposit which has been tested and found to yield a good grade of fire brick. West of Guthrie Center, near the fair grounds, are beds worthy of a test. The

Missourian formation as represented in the county is a limestone and hence has no value in this connection.

The loess is abundant and easily manipulated. Its distribution may be seen on the map of the surface deposits. Its character has already been described. The following analyses, made by Prof. G. E. Patrick, shows its composition:

	PERCENT
Hygroscopic water	2 78
Combined water	3 55
Silica $Si\,O_2$	68 62
Alumina $Al_2\,O_3$	14.98
Iron oxides calculated as Fe O	4.16
Manganese oxide calculated as Mn O	.64
Lime Ca O	1.48
Magnesia Mg O	1 09
Soda $Na_2\,O$	1.86
Potash $K_2\,O$	1.50
Total	100.66
Error	.66

The sample was taken from the pit of Mr. W. E. Berry at Guthrie Center and is apparently fairly representative for the region. The material will be seen to be less siliceous than is usual for loess and higher in alumina. It is adapted to the dry-press, but could aparently be also worked as a stiff mud. It should make an excellent face brick of good strength and color.

The alluvium, so commonly present along the streams outside the Wisconsin drift area, is, as usual, well suited for the manufacture of common stock brick by the hand process. It is easily and inexpensively worked and affords a cheap brick of good quality.

A considerable growth in the brick industry may reasonably be expected as the wealth of the region increases. This growth will probably result from the better treatment of the loess and the wider use of the shale both alone and in mixtures. In the northeastern portion of the county the loess is covered by the drift, which is not itself adapted to manufacture into brick, and in this region the main dependence

must be the coal measure shales and clays removed in mining works, together with occasional patches of surface soil accumulated in sloughs.

The treatment given the clays in the county is usually slight. The hand process or simple machinery alone is used, though the Berry plant at Guthrie Center is well equipped, and the Panora Brick & Tile works are contemplating extensive improvements. The details of processes and machines are given in the description of the individual plants.

The W. E. Berry brick works is located at Guthrie Center, near the Rock Island track, southeast of the depot. It was started as a hand yard eight or ten years ago. At the end of two years the "Eureka," a stiff mud machine, was put in, and brick were made by this process until 1893, when a Boyd dry-press was introduced. The material now used is loess obtained from a low slope, immediately adjacent to the plant. The top eighteen inches of soil is removed, the under material is plowed, and when dried is hauled to sheds. The perpendicular face of the clay is nineteen feet. Underneath the loess the Cretaceous sand bed lies exposed, the glacial deposits usually found between the Cretaceous and loess apparently being absent. The product from the first kilns was not promising, but by the close of the season, as less sandy loess was used, and the necessary treatment both in the machine and in the kiln became understood, the quality of the finished brick was improved. In burning the brick a down-draft kiln and one ordinary clamp kiln are used, most of the brick being burned in the down-draft. The brick are carried direct from the press to the kiln.

The Stuart Brick & Tile Works is about three-fourths of a mile north of the depot at Stuart. The raw material consists of ten feet of ordinary loess grading into soil at the surface. The base of the cut rests on coarse drift gravel, which is about three feet thick, and this rests in turn upon glacial clays. The product, structural brick, sidewalk blocks and draintile, are made on the Decatur machine and burned in

either a closed down-draft or a semi-clamp kiln. The ware has a dull red color, and is very firm. Farther up on the hillside near by, a test pit was put down, and underneath the yellow clay, a gray plastic loess, four feet thick, was penetrated. This lower bed has not been used, as it was found to contain much lime. The clay now used is worked as a stiff mud with a good deal of water. The ware is dried under sheds with very little cracking.

The Panora Brick & Tile Works includes quite a large plant just southeast of the city limits, along Middle Raccoon river. It has been in operation for a number of years, starting with a Eureka stiff mud machine. Later a Hoosier mill was substituted, and this in turn has given place to a Frey-Sheckler. A section of the pit has already been given. For ordinary work all the shale, with the exception of the bituminous portion, is mixed together, and occasionally a little surface clay is added. For fine red brick the upper shale alone is used. The clay is ground in a dry-pan made by the Des Moines Manufacturing Co., and then pugged on a mill made by the same company. The brick are loaded upon iron trucks, and either run under dry sheds of 70,000 capacity, or through a tunnel drier holding 25,000. Under the dry sheds about three days time is required, while the tunnel drier does its work in twenty-four to thirty hours. Four down-draft kilns with a capacity of 200,000 are used in burning; five days, with full blast for thirty-six to forty-eight hours being required.

Directly west of Panora on the Guthrie Center road (Tp. 79 N., R. XXX W., Sec. 6) is the Horton brick yard, where the loess, fourteen feet thick, is used in making hand brick, which are burned in cased kilns.

Mr. W. B. Simon & Son, the owners of the Greenbriar mine, operate a brick plant near the latter. They make both brick and tile, using three kinds of clay. The fire clay from below the coal is mixed with the black shale above it, and the surface soil taken to a depth of three feet from a hillside. The material is worked as a stiff mud, dried under sheds, and

burned in one round down-draft kiln. The brick are hard and of good color.

Building Stones.

Material suitable for building purposes may be obtained from all the formations in the county. From the Pleistocene may be taken bowlders of granite and similar rock; from the Dakota and Des Moines sandstones, and from the Des Moines and Missourian limestones may be obtained. With the exception of the limestones of the Missourian, none of these sources are likely to become important. The bowlders are scattered and the cost of collecting and dressing them is more than that of shipping in more easily obtained stone. In certain other counties in the state the drift bowlders have been more or less used for special work. In this region they are often called into requisition for foundations and well and cellar walls, particularly in the northeastern portion of the county where nothing else is obtainable.

The sandstones both of the Dakota and the Des Moines are soft and of but limited value. They afford, however, a sufficient supply of stone for local rough use. The gray sandstone at Panora has been quarried a little, but is not used for fine work.

The limestones of the Des Moines are thin and of limited distribution. They will not afford a supply of much importance. The Missourian formation is represented in the county by the Fragmental and Earlham limestones of the Bethany with a few beds of the Winterset. The Bethany is extensively quarried in Madison, Clarke and Decatur counties. It has been opened up at a few points along Raccoon river and Deer creek. The openings are not extensive enough to give much of an idea of the stone, but apparently it is of the same character as that at Earlham and Winterset. A total thickness of nearly sixty feet is known to occur, and a good portion of this is suitable for building stone.

Sand.

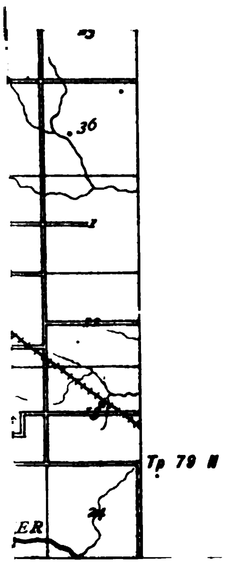
Sand suitable for building purposes may be obtained from the bottom lands along many of the streams and from the Dakota. The latter is an important source of such material. The section of the pit of Mr. Samuel McLune, in the northwestern portion of Guthrie Center, has already been given. The lower sand here is clean, white in color, and easily worked. About 150 yards of building sand have been taken from the pit. Sand is found in the Dakota at a number of other points but has not been extensively opened up.

The drift sand found near Stuart was formerly used in the manufacture of hand brick. Since the introduction of machinery and the employment of the loess the sand is not needed. It is clean and of even grain but is too well rounded to be of the highest utility as a building sand.

Gravel.

There are two sources of gravel in the county. The first is the gravel terrace along the Middle Raccoon and the second is the gravel or conglomerate bed of the Dakota. The terrace gravel has not been used within the county except for local work. At Coon Rapids, just outside the county, on one hand, the Chicago, Milwaukee & St. Paul railway has opened up extensive pits. In Dallas county, on the other, both the Chicago, Rock Island & Pacific railway and the Des Moines Northern & Western railway have opened up pits. The gravel from this horizon is hard, uncemented and easily worked, but is usually quite sandy.

The gravel or conglomerate of the Dakota is widely spread throughout the western three-fourths of the county. It is frequently so completely cemented as to be unavailable, but at other points is loose and easily worked. The Chicago, Rock Island & Pacific railway has opened up pits between Menlo and Glendon along the Guthrie Center branch. The gravel is very hard, being formed of the most durable material. It has sand beds interstratified with it, but is usually rather free



H. F. BAIN
1897.

LEGEND

from sand within the gravel. It is an excellent material for railway ballast.

Natural Gas.

One of the most interesting features in connection with the drift is the occurrence of natural gas. At Herndon gas has been found in a number of wells, and while only two wells are now burning, a considerable area has been shown to be underlain by it. This was at one time the cause of a considerable boom in real estate, but it has recently received very little attention; less in fact than it deserves. According to Mr. J. E. Stout* the gas was first discovered in October, 1886, in a well put down for Mr. F. Gardner. The well was being bored for water, and at 120 feet gas was encountered. This well was shut off without being used, as was also the first one put down for Mr. H. C. Booth, in November of the same year. A second well put down for the latter gentleman furnished gas for heating and cooking for a year or more. A number of other wells were put down, all going to a depth of from 120 to 140 feet. In most of these gas was encountered and from many of them it was used. In no case did the wells penetrate anything other than the drift and in all cases a fine sand or mud with the gas gave trouble. This mud was never successfully cased off and would flow into the pipe until the gas below accumulated sufficient force to throw out the mud. This of course made an explosion and usually resulted in the gas pipes being taken out. The mud choked up the well within a few months in most instances, when it was necessary to put down another well in order to obtain a new supply. At present but two wells are burning, one near the railway station, and the other on the Leber farm a mile and a half west of town. Neither is in use. In one well on the Pierce farm near Yale, gas was encountered in 1887 above the artesian water, but was never used.

The pressure of the gas seems never to have been measured. According to Dr. Jones, now of Herndon, in one case a two-inch

*Rept. Stat. Mine. Inspector, 1887, 163-170.

pipe furnished gas for a flame twenty to twenty-five feet high and about eight feet across. At Dawson, a few miles east of Herndon, similar wells had a pressure of twenty-four to twenty-five pounds.* At Letts, in Louisa county, gas wells of the same type are said to have had a pressure of five to twelve pounds.† The Leber well now has a pressure which, judging from the size of the flame, must be considerably more than the pressure in ordinary city pipes. No analyses of the gas has been made. Call,‡ who visited these wells soon after the gas was first struck, referred the origin of the gas to the decomposition of the vegetal matter of the forest bed. McGee§ has concurred in this view. Most of the wells are not driven deep enough to encounter the forest bed, though it is known to be present and has been encountered in deeper wells. The origin assigned by Call is doubtless the correct one. It accords well with the facts observed in other regions, as at Letts, Iowa; Bloomington, Kankakee and other points in Illinois and other states¶. In all these cases it will be observed that the gas is encountered near the edge of an overlying drift sheet. It is but a short distance southwest of Herndon to the edge of the Wisconsin drift. Letts is near the border of the Illinois drift and Kankakee is near a well developed moraine which seems to mark the border of the late Wisconsin. The forest beds when developed between drifts are more apt to be well preserved where they have been passed over by only a small portion of the succeeding ice. They are, in places, preserved far back from the edge of the overlying drift, but the chance of preservation decreases with the distance from that edge. These facts give a new economic significance to the tracing of the limits of the drift sheets.

*Leonard: Proc. Iowa Acad. Sci., vol. IV, p. 43. 1897.
†Witter: Proc. Iowa Acad. Sci., vol. I, pt. iii, pp. 63-70.
‡Mon. Rev. Iowa Weather Serv., Nov., 1892, pp. 6-7.
§Eleventh Ann. Rept., U. S. Geol. Surv., p. 585.
∥Witter, Loc. cit.
¶McGee: Op. cit., p. 586.

The area in the county in which gas wells may be found is not large. It is confined to the area of the Wisconsin drift. The numerous wells put down for water throughout the region show very clearly that the gas territory is only a small portion of the Wisconsin area. It is of course highly probable that gas will be encountered at points not now known, but the presence of many artesian wells showing either no gas or only small amounts narrows the area of probabilities.

It seems probable that the gas may have more of an economic importance than has been heretofore allowed to it. It is of good quality, sufficient pressure and cheaply obtained. While the quantity is not great, certainly not sufficient to warrant an attempt at piping it to other cities, there is no reason to believe the supply inadequate for local demand. Such gas is in use at other points both in this and neighboring states, and at certain points wells have been used for six or seven years with no apparent diminution of pressure. In the Herndon wells the trouble arose from the water and sand which filled the pipes. It certainly seems that adequate study would result in some device for clearing the gas and thus making available a highly valuable local fuel.

Water Supplies.

Guthrie county is well supplied with water. The numerous streams of the central and southwestern portion of the county and the miniature lakes of the northeastern portion afford an abundant supply of surface water. The drift deposits which cover the area contain numerous water horizons so that there is rarely any trouble in getting a good well. The base of the drift is usually a reliable horizon. At Stuart an excellent supply of water is obtained from a white sand lying below ninety feet of drift, the water being, however, charged with magnesia, which is deposited in the tanks and pumps. The water has been used for some years as a boiler water by the railway company, and has recently been adopted as a supply for the city water works.

The gravels, sands and loose sandstones of the Dakota may usually be relied upon to furnish water. At Guthrie Center the city water works draw their supply from a well in this formation. The limestone of the Missourian are not so reliable, and the Des Moines beds are apt to furnish mineralized water.

In the northeastern portion of the county near Bagley, Herndon and Yale there are numerous artesian wells, all obtaining their supplies from the drift. They are, in the main, of slight depth, but vary in that particular. The old Yale well is twenty-three feet, the Bartlett well is 140. At Bagley there are six wells inside the town all less than sixty feet deep. In some places the water is so close to the surface that it forms springs. The water has usually a fair but not high pressure. The Yale well fills a half-inch pipe with a strong stream. It is nine years old, and formerly filled a three-fourths inch pipe. The Eastwood well runs a two-inch stream, and will rise to twenty feet. Most of the wells rise only three to four feet above the surface. One of the wells near Bagley would throw an inch and a half stream twenty feet high. The stream is now reduced, and the water carried up to the house near by.

The source of the water is evidently local. The topography of the country is that of swells and basins, with a relief of twenty to thirty-five feet. The wells are located on the lower lands, and in no case do they throw water higher than the highest land of the immediate vicinity. Certain of the wells interfere with each other, but in general they do not seem to do so. During the recent dry years it was noted that some of the wells showed a slightly diminished flow.

There seems to be no single water horizon. It has not been found possible to relate the flow to any definite bed in the drift. The latter is here as usual quite heterogeneous. The beds of bowlder clay contain sandy and gravelly portions well calculated to catch and transmit water. These are present in the drift of the entire county, and for that matter are usual

throughout the state. They form the source of a large majority of the shallow wells of the state. The water here, as elsewhere, seems to be derived from local precipitation. The average annual precipitation for Guthrie county is probably about forty inches. Unfortunately there are no complete figures for the county, and the matter must be judged by measurements made in the surrounding region. At Atlantic the amount is 41.47, at Audubon, 43.75, and at Carroll, 41.83.*

A precipitation of forty inches would amount to a daily average of 1,600,000 gallons per square mile.

When water falls on the ground a portion is evaporated, a portion is absorbed by the ground, and a portion is carried away by streams. The amount which runs off through the streams is quite variable. It depends upon the slope, character of the rocks, distribution of the rainfall and other lesser factors. The best estimate for the streams of this region are those of Greenleaf,† who gives the run off of the Des Moines river as 20 per cent, and of the Skunk as 24 per cent. Of the total precipitation, then, at least 320,000 gallons per square mile is daily carried away by the ordinary streams of central Iowa. Any region of incomplete drainage has a surplus of water proportional to the imperfection of the drainage. This surplus must either stand on the surface till evaporated or soak down into the soil. Evaporation is more rapid in an undrained than a well drained area, other conditions remaining the same, but the ratio of increased evaporation is problematical. There is also large seepage, and the ground becomes more heavily charged with water. Such are the conditions which prevail in that portion of Guthrie county under discussion. As has been previously noted, the region covered by the Wisconsin drift is marked by few streams, and many ponds and shallow lakes. Very little of the water is carried off by surface streams, and the ground is at all times quite saturated. Upon each undrained acre there is an average annual surplus

*Ann. Rept. Iowa State Weather Serv., 1895.
†Tenth Census U. S. vol. XVII, pt. ii, p. 20.

of 1,825,000 gallons. Under such conditions the water will penetrate every stratum which is permeable, and will take advantage of every favorable condition for flow. With a local relief of thirty to occasionally forty feet, and strata containing many irregularly distributed beds of open texture alternating with stiff clays, there must be many points at which flowing artesian wells may be found. The number of the wells, the slight depth, the moderate flow, the occasional interference, the variation, though slight, with the rainfall and the structure of the region, all unite to show that this is the true explanation of the phenomena. In some cases the water probably goes to the base of the drift, and is carried by the gravel usually found along that horizon; in other cases the water is probably carried by the loess between the two drifts. In many cases it is carried by local sandy and gravelly beds in the drift itself.

Soils.

The soils of Guthrie county are its great source of wealth. They include all the main types which occur in drift covered regions. In the northeast is the drift soil itself, along the rivers are the rich alluvial bottom lands, and over the divides of the central and southwestern portion of the county is a top dressing of loess on the loose and weathered Kansan drift. The areas covered by each of these soil types are indicated upon the map of the surface deposits. The characteristics of the different beds have been suggested in the discussion of the Pleistocene. As soils their variations are mainly due to differences in texture and structure. The composition of each of the two drift sheets as a whole is probably not greatly different. The loess and the alluvium represent the finer portion of the drift gathered together. The composition is much the same but the texture is very different. The drift is heterogenous; the loess homogeneous, and the alluvium, sometimes one and sometimes the other. The fine texture, porosity and homogeneity of the loess greatly influences its behavior toward water. The latter is distributed more equally

through it and is furnished evenly to crops. In the drift region the water is irregularly distributed, and this, with the immature drainage, makes artificial ditching and tile drainage necessary over considerable areas. So sharp are the differences between the two areas that in Jasper county, where the same relations obtain, entirely different culture is found on opposite sides of the stream which flows along the drift margin. This extends even to the character of the plows, those on one side of the stream refusing to scour in the soil on the opposite side.

In this county, as in other portions of the state, it has been found that fruit does better on the loess than the drift soils, while, when the latter is suitably drained, wheat and even corn usually give a larger yield upon the drift. There are, of course, exceptions and other factors must be taken into account, but that these different formations have different soil values is abundantly proven. The determination of this value and the adaptabilities of the different types as well as the nature and causes of the differences is a matter which will require much future study.

GEOLOGY OF MADISON COUNTY.

BY

J. L. TILTON AND H. F. BAIN.

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CONTENTS.

INTRODUCTION.

Madison county lies in the south central part of Iowa in the third tier of counties north of Missouri. North of it is Dallas county, while to the east is Warren; to the south, Clarke and Union, and to the west, Adair. In form it is an approximate square and includes sixteen congressional townships; townships 74–77 north and ranges XXVI–XXIX west. Owing to errors in the original survey the area is only 566.4 square miles instead of the customary 576.

Geologically the county is of especial interest because of the fact that the Bethany limestone, forming the base of the Missourian formation, extends across it. An opportunity is thus afforded for a study of the relations between the productive and the non-productive portions of the coal measures. Winterset, the point at which the Bethany limestone was first studied in detail in Iowa, is the county seat and is located near the center of the county on the border between the Missourian and Des Moines stages of the Carboniferous.

In the course of his work in Iowa White spent some time in Madison county studying particularly the limestone. His

observations were published in part in 1868* and more fully in 1870.† The position and thickness of the limestone were determined, and its most characteristic fossils were noted. It does not seem that previous to this the limestone itself had ever been studied; though the higher beds of the Missourian as exposed along the Missouri river had been referred by Owen to the Sub-carboniferous, and by Geinitz, Marcou and others, in part to the same formation and in part to the Permian. More recently there has been considerable discussion in regard to the proper division of the coal measures and the correlation of the limestone found at Winterset with the Bethany limestone of Missouri and the Erie limestone of Kansas. For these reasons it has seemed desirable to make a detailed study of the outcrops which were taken by White as the type for the formation. It was hoped that data might be collected which would be of service in these broader correlations.

The work was begun some years since and in a preliminary paper‡ a section was given connecting the Winterset limestone with the Ford sandstone, the relations of which to the underlying strata had been determined by Keyes.§ In the report upon the coal deposits of the state‖ a few notes were also given on the coal beds of the county.

In the present work the authors have had the assistance both in the field and the office of Professor Calvin, and to him is due particularly the determination of the fossils. Notes on the building stones of the county collected in 1894 by Mr. Arthur C. Spencer have been freely used. While indebted to many people within the county for numerous acts of kindness, we are especially indebted to Mr. Paul Price, of Winterset, for assistance in collecting fossils. Acknowledgments are also especially due to Mr. J. A. Wilkins, of the

*First and Second Annual Reports of State Geologist, pp. 70-78. Des Moines, 1868.

†Geol. Iowa, vol. I, 241-250, 305-316. Des Moines, 1870.

‡Tilton: Geological Section along Middle River in Central Iowa. Iowa Geol. Surv., vol. III, pp. 135-146. 1897.

§Bul. Geol. Soc., Am., vol. III, pp. 277-292. 1891. Also, Iowa Geol. Surv., vol. I, pp. 94, 107; vol. II.

‖Iowa Geol. Surv., vol. II, pp. 304-306. 1894.

same city, for the excellent blue print from which the accompanying map was drawn. The work as originally planned was not to be completed until the fall of 1897 but it became necessary to finish it much sooner, and in the absence of the senior author the work was completed by his associate. To this change in plan may be charged any minor omissions or lack of detail which may be noted.

PHYSIOGRAPHY.

TOPOGRAPHY.

Madison county lies on the eastern flank of the great divide between the Mississippi and the Missouri. The divide itself runs through Adair, the next county to the west. The area under discussion forms a portion of a much dissected upland plain, sloping to the northeast about ten feet per mile. In the southeast the high divides between the rivers rise from 950 to 975 A. T. Earlham, Winterset and Truro, all located on the upland and approximately in line, are 1,116, 1,127 and 1,078 A. T. respectively. Still further west, Stuart and Lorimer, in a line parallel to that passing through Earlham and Winterset, are respectively 1,216 and 1,230 above tide. Beyond this the surface maintains its slope to between 1,400 and 1,500 feet at Adair. This general plane, which the divides touch, is very much cut by erosion. At Bevington, Middle river has cut down to 833 A. T. At Lida, near the east county line, North river has reached 840 A. T. At Afton Junction, a short distance south of Madison county, Grand river has cut 210 feet below the upland, or to about 1,040 A. T. These three rivers drain the greater portion of the county, and the depth to which they have cut has made it possible for their many tributaries and minor feeders to cut to corresponding levels.

The land forms seen within the county are exclusively erosion forms. The later ice sheets did not extend into this area, and the length of time since the Kansan drift was deposited has been so great as to allow the streams entirely to destroy any peculiar drift topography which the county may once have had.

While the topographic forms have all been developed by erosion acting on a probably even plane, the differences in the character of the underlying rocks have been so great as to produce two distinct topographic areas. These correspond quite closely to the areas shown on the accompanying geologic map as underlain respectively by the Missourian and Des Moines formations. The former terrain, so far as this county is concerned, is made up principally of limestone. As will be seen later there are important shale beds present, but it is the limestone which controls the topography and gives it its distinctive character. The Des Moines terrain is as usual made up mainly of argillaceous and arenaceous shales, soft

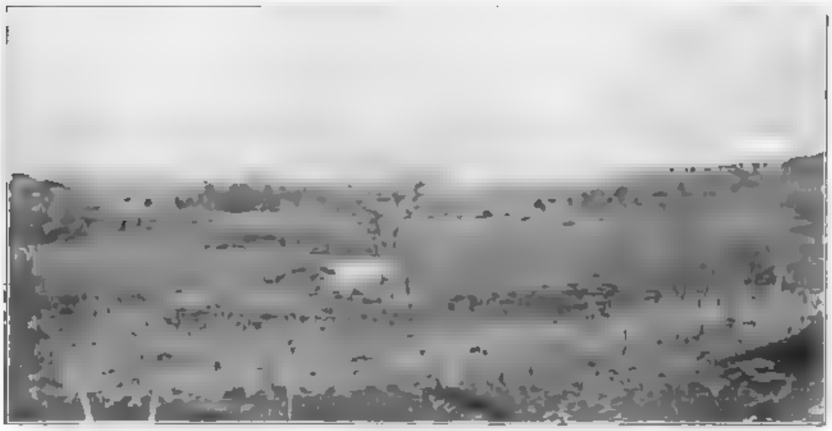


FIG 72. View down Middle river valley from a point about one mile east of Buffalo. The limestone is in the hills on either side.

sandstones, thin coal seams and easily eroded beds. There are only a few limestones, and those present are so thin as not to affect the topography to any marked extent.

As will be seen by the map, North river and Middle river have cut through the Missourian and exposed the Des Moines more than half way across the county. The minor streams, Bulger, Cedar and Jones creeks, produced results of like character, but of less extent. The valley of Clanton creek is essentially like the others in origin and character. These

valleys in the limestone country are as much as 200 feet deep and in places a mile and a half to nearly two miles wide. They have been cut by headwater erosion, and mainly by undermining of the various limestone ledges. If one travels toward the source of one of these streams, or some one of its tributaries, he will pass along a flat bottomed, canyon-like valley, until the point where the river crosses the limestone is reached. The different ledges of the latter are crossed by the stream in a series of abrupt falls or rapids. Above the latter the river becomes a mere prairie stream, with a shallow valley having gently sloping sides. In the case of the major streams the falls have been almost entirely cut away so that the crossing of the limestone is marked only by shallow rapids. The shortness of the lateral tributaries below the prairie portion and before the streams reach the region where they are uninfluenced by the limestone is worthy of notice. Some of the small streams running south from Winterset to Middle river make the whole descent of nearly 200 feet in a mile or less.

The divides between the major streamways are characteristically flat topped. Over much of this central and western portion of the county the drift is usually thin, and the streams over the upland portion have developed only the faintest relief. The limestone has sharply limited the amount of erosion that could take place over the upland, and while the time has been long—so long indeed that the whole country has been invaded and reduced to slope by feeble streams of slight grade—the relief is so little that the predominant effect is one of flatness. As one looks off over the country he sees only a broad even plain, and the semblance of a plain is preserved up almost to the brink of the wide, trough-shaped valleys which tell of the immense time through which the rivers have been at work.

In the eastern portion of the county but little of the old plain is left. The impression which a glance at the topography gives is rather one of hills and valleys. The main streams have a network of tributaries which reach out and

cut into almost every foot of intervening territory. The relief is usually 120 to 160 feet, so that large areas of level land are rare. The region east of Clanton creek forms a table land at about 1,050 to 1,075 A. T., and has been but little invaded by streams. It is held up by the underlying limestone.

Throughout most of the eastern region the action of the streams has been unhindered. The loess, drift and coal measures have approximately the same degree of hardness, and

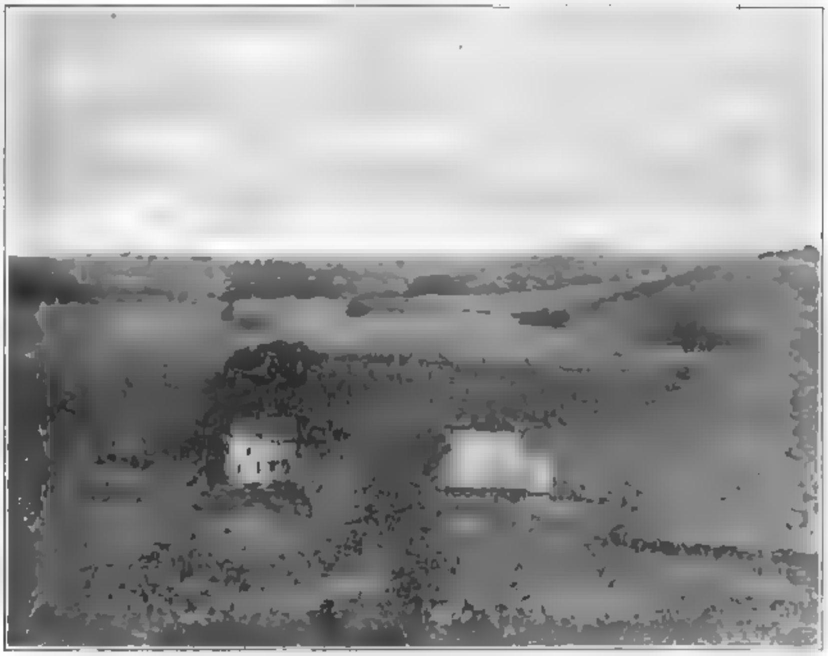


FIG. 73. View down the valley of Cedar creek in Union township (section 22), showing hill slopes of the Des Moines formation.

the profiles form continuous curves. These are usually paraboloid in character with the upper arm relatively long and showing a gentler slope. The lower portion of the curve is in most cases merged into a long gentle concave curve, which in turn passes into the almost straight slope of the river bottom land. In some instances the lower concave portion is absent, and the parabola meets the flat surface of the bottom land quite

abruptly, as if there had been recent filling in of the valley by material not derived from the sides. The valleys are broad and have well developed flood plains. The streams are not deepening their channels, and the major erosion in the county is in the western division. At places along the valleys there are the usual sloughs, marking the half-filled cut-offs left by the meandering river. In general the streams flow along the southern sides of their valleys, which is accordingly steep as compared with the long, gentle slope to the north.

TABLE OF ELEVATIONS.

The following elevations of points within the county or near its borders have been taken in part from Gannett's Dictionary of Altitudes, and in part from the profiles of the various railway lines.

STATION.	Altitude.	AUTHORITY.
Barney	1053	C. Gt. W.
Bevington	849	C., R. I. & P.
Clanton creek, north of Hanley	878	C. Gt. W.
Clanton creek, west of Barney	1066	C. Gt. W.
Earlham	1116	C., R. I. & P.
Hanley	858	C. Gt. W.
Lorimer	1230	C. Gt. W.
Middle river at Patterson	854	C., R. I. & P.
Peru (East)	948	C. Gt. W.
Stuart	1216	C., R. I. & P.
St. Charles	1066	K. & W.
Truro	1078	K. & W.
Winterset	1127	C., R. I. & P.

DRAINAGE.

The major portion of the drainage of this county finds its way through the Des Moines to the Mississippi river. A smaller portion passes through Grand river south to the Missouri and thence to the Mississippi. The larger streams of the county are North and Middle rivers, and Clanton creek, a tributary of Middle river, which joins the larger stream in Warren county. North of the North river drainage basin is a small area, including about ten square miles, which sends its

waters through Bulger creek to the Raccoon river. Southeast of Clanton creek and beyond the Truro-St. Charles upland, is the basin of South river, including in this county thirteen and five-tenths square miles. The Grand river basin lies in the southwestern portion of the county and includes twenty-eight square miles. Of the remainder of the county North river and its branches drain 246.5 and Middle river and Clanton creek 268.4 square miles.

North river, Middle river and Clanton creek originate as prairie streams above the limestone and flowing down over

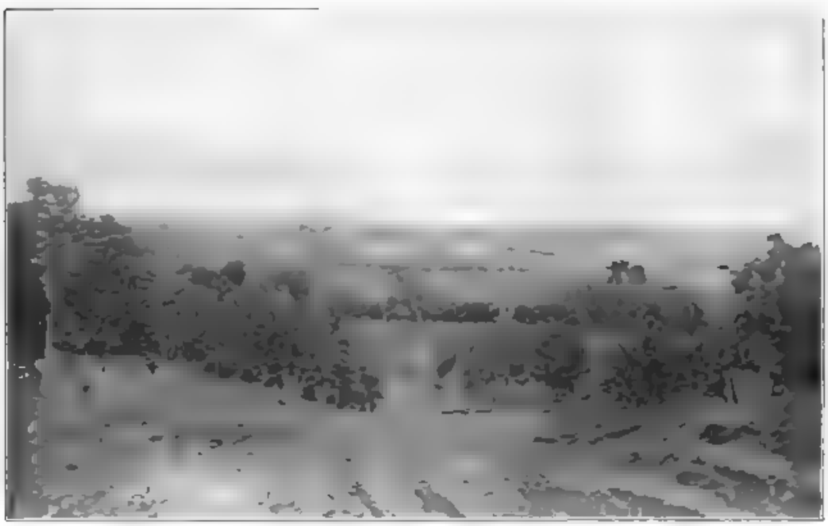


FIG. 74. View across the valley of Clanton creek toward Hanley.

the latter passes over the Des Moines formation in the broad valleys with gently sloping sides, already described. Bulger, Cedar and Jones creeks are essentially similar. Grand river flows parallel to the edge of the limestones and, throughout the county and for many miles after leaving its borders, flows over the drift. With the exception of Grand river the larger streams and many of the minor ones are flowing generally in preglacial valleys. The valley of Middle river below the "Backbone" (sections 16–15, Lincoln township), North river,

Cedar creek, Steeles branch, Jones creek, Clayton creek, Hay branch and South river all have in their valleys undisturbed drift and loess which determine their preglacial age. They do not, however, always exactly follow the older courses. Clanton creek is in a preglacial valley from Hanley to Barney, but it may be doubted whether its upper portion occupies the main part of the old channel. In sections 27 and 35 of Walnut township there is a great thickness of drift which is suggestive of a filled in valley.

Middle river has had an interesting history. The present stream had its source in the southwestern portion of Guthrie county. In its upper course in Guthrie and Adair counties it runs over the drift. In Madison county down to the locality known as the Devil's Backbone it runs generally on the drift, but occasionally cuts into the limestone in such a manner as to indicate a drift-filled valley only partially cleared. From section 21 of Lincoln township a preglacial valley, now filled with Kansan drift, extends in a winding southwesterly direction from the mouth of Fletcher branch across section 31, thence crossing westward through sections 3 and 10 of Grand River township, running south of Macksburg through sections 16, 21 and 28.* This old valley is comparable in size to the present valley of Middle river and seems, in fact, to have been its former extension, or at least the valley of an important tributary. In preglacial times Middle river accordingly drained an area to the southwest which is now served by Grand river.

Upland meanders as defined by Marbut† are excellently exhibited on Middle river. The best example is the Devil's Backbone already mentioned. The river here makes a long bend to the northward and back to within a few hundred feet of the starting point. Both above and below this point the valley is marked as usual by steep bluffs on the south and longer, gentler slopes at the north. At the Backbone this is reversed. The outside of the broad crescentic curve is

*Tilton: Proc. Iowa Acad. Sci., vol. IV, p. 51. 1897.
†Missouri Geol. Surv., vol. X, p. 93. 1896.

marked by abrupt rocky bluffs. The tongue of land around which the river runs slopes gently to the north. It is composed entirely of rock, as is well shown by the numerous exposures, so that the appearance cannot be due to filling in. In all essential particulars it agrees with the meanders described by Marbut and is similar to the Keosauqua bend illustrated by Gordon.*

The meander must have been developed *in situ*, as has been urged for similar meanders in Missouri by Winslow.† It is not to be interpreted as due to inheritance, as proposed by Davis,‡ since the two rocky sides have such markedly inequal slopes; slopes which in this instance are the exact reverse of the normal slopes throughout the region. A slight obstruction or inequality originally throwing the stream to one side set in motion the chain of processes by which the river was thrown farther and farther to the north at the same time that it cut step by step into the limestone. By constant undermining the north wall was kept steep, while by the constant shifting of the stream the south wall was preserved from similar action. It seems to have been this action, continued for a long time, which produced the broad curve and the Backbone. Clanton creek, where it crosses the limestone between Barney and Peru, shows upland meanders quite as perfect as any on Middle river.

The general character of the preglacial surface of the county may be inferred from the present topography. The drift is throughout most of the area relatively thin. At many points it is almost absent. The high, flat-topped divides and the broad, yet canyon-like valleys, were present then as now. The relief was probably somewhat greater, and in part of the county may have been as much as 300 feet. The eastern portion was then marked by less abrupt slopes, as it is now, and the southwestern portion seems to have been cut to a general altitude somewhat lower than that of the eastern edge of the limestone.

*Iowa Geol. Surv., vol. IV, plate VII. 1895.
†Science, vol. XXIII, pp. 31-32. 1893.
‡Science, vol XXII, pp. 276-279. 1893.

The time when the streams of the region originated cannot be sharply fixed. The youngest indurated rocks in the county belong to the Missourian. The Cretaceous may formerly have covered a portion of the area, though there is no direct evidence on the subject. Above the limestones of the Missourian there are only the residual clays and the drift deposits. As has been seen the region shows evidence of a former plain into which the streams have cut. It seems probable, however, that this plain could not have been a base level; at least, that it was not a base level which had required a long time for its development. There is some slight evidence in the thinning of the various limestone members of the Missourian toward the northeast that the original shore line of the Missourian seas passed through the county and that the shore deposits, very little eroded, are still preserved. If this be true, it follows that the country stood relatively low, or was, at least, preserved from great erosion from the time when the limestone rose above the sea to the cutting of the present valleys. This hypothesis is to be received with caution since it controverts supposed changes in altitude adduced from study of the surrounding counties, and is itself improbable in that it postulates a freedom from change for a longer period of time than has been usual in the earth's history.

Whenever the streams originated, they have in the main held their courses ever since. They belong to the resurrected type characteristic of the Kansan drift.* Many minor changes took place in the course of the glacial period and in recent time a considerable amount of cutting has been done. The most striking fact in relation to the drainage is its age and completeness, and while the recovery of a once completely drained area by a series of resurrected streams would be relatively rapid, these facts can only be interpreted as indicative of a very long period of time since the ice left the region.

*Bain: Iowa Geol Surv., VI, 458-460. 1897.

STRATIGRAPHY.

General Relations of Strata.

The strata exposed in Madison county belong to two groups widely separated in character, origin and age. The underlying indurated rocks belong to the Carboniferous; the overlying unconsolidated beds belong to the Pleistocene. Between the two is a great unconformity indicative of a long time interval. Possibly in the drift-covered southwestern portion of the area, outliers of the Cretaceous occur between the Carboniferous and the Pleistocene. No such beds, however, have been seen in the field or reported from drill holes Fragments from the Cretaceous conglomerate seen in Guthrie county occur commonly in the drift of Madison, but at present there is no sufficient evidence for believing that the beds occur *in situ* within the limits of the county. From the close of the Carboniferous, perhaps from the early part of the Upper Carboniferous, to the oncoming of the great glaciers of the Pleistocene, Madison county seems to have been the scene of erosion rather than deposition; and yet, as has been suggested, the amount of erosion accomplished in that interval, while great as compared with that now being carried on, is small as compared with the length of the time.

The beds of the Carboniferous include rocks which make up two series of strata. The lower series is composed of sandstones, shales, coal seams and a few thin limestones. It is the Des Moines formation and includes the beds which White referred to the middle and lower coal measures. The upper series is the Missourian and is represented here by the Bethany limestone with the intercalated shales. It answers to the Upper Coal Measures of White. Both the Des Moines and the Missourian belong to the Upper Carboniferous series defined by Branner as the Pennsylvanian and currently known as the coal measures.

The Pleistocene beds include the modern alluvium, the loess and the Kansan drift sheet. An earlier drift sheet is perhaps present but has not been differentiated.

The taxonomic rank of the various formations is shown in the following table.

GROUP.	SYSTEM.	SERIES.	STAGE.	SUB-STAGE.
Cenozoic.	Pleistocene.	Recent.		Alluvium.
		Glacial.	Iowan.	Loess.
			Kansan.	Drift.
Paleozoic.	Carboniferous.	Upper Carboniferous. (coal measures)	Missourian.	Bethany limestone.
			Des Moines	

Geological Formations.

CARBONIFEROUS.

DES MOINES FORMATION.

The strata referred to the Des Moines are the oldest beds outcropping in the county. They underlie the eastern portion of the county and are cut into by the river valleys. Only the upper portions of the Des Moines formation outcrop within the county; the earlier beds of this stage lie below the level of the valleys of erosion. The lowest beds known in the county are probably 350 feet above the Saint Louis limestone, which lies just beneath the productive coal measures. Sections along Raccoon river by Keyes, and along Middle river by the senior author, indicate the character of the lower beds.

The Des Moines formation is characteristically a complex of shales of many kinds, sandstones, coal seams, and thin limestones. In its lower portion there is a marked lack of persistence of individual beds. The rapid and complete lithologic changes which the strata undergo have so far made it impossible to trace individual beds for any great distance. To a certain extent this is true of the upper portion of the Des

Moines formation as shown in Madison county, but in general the characteristics of individual beds persist over wide areas. In Guthrie and Dallas counties Mr. Leonard and the junior author recognize a well defined series which extends under a portion of Madison county. Farther south, however, the character of the formation changes somewhat so that it is only possible to make the most general correlations between the Des Moines beds of southeastern Madison and those farther north.

The best exposures of the Des Moines so far noted within the county may be found in South township along a stream running down to Clanton creek not far from Hanley (sections 35, 34 and 27). Starting from the Fragmental limestone, which is regarded as the base of the Bethany and exposed not far from the Des Moines & Kansas City railroad, the following section is exposed.

		FEET.	INCHES.
22.	Shales, drab, argillaceous, with abundant *Derbya crassa*, *Chonetes*, probably *Chonetes parvus* Shum., at the top	12	
21.	Shales, red, argillaceous	3	
20.	Limestone, fragmental, earthy, with bits of fossils		2
19.	Shale, blue to green, argillaceous, grading into red below	3	
18.	Shales, blue to green, sandy, with nodular segregations of limestone	12	
17.	Shales, blue, calcareous	12	
16.	Limestone, compact		2
15.	Limestone, fragmental, loose, with young *Conetes mesoloba*		10
14.	Limestone, fragmental, but firmly cemented, reddish color, with *Spirifer cameratus* and *Productus costatus*	1	
13.	Shales, green, argillaceous	29	
12.	Limestone, blue to black, in two ledges, with *Spirifer cameratus*, *Rhynchonella* and *Productus*	1	
11.	Shale, carbonaceous	2	
10.	Shale, clayey, drab	1	
9.	Shale, yellow, sandy, with marked horizontal bedding planes	4	
8.	Shales, black to drab, carbonaceous		6

		Feet.	Inches.
7.	Limestone, nodular, sandy, with *Productus cora*, *Chonetes mesoloba* and *Athyris subtilita*	1	4
6.	Shale, gray, sandy	3	
5.	Limestone, similar to number 7		10
4.	Shale, clayey, drab to blue		10
3.	Shale, carbonaceous	1	
2.	Limestone, thin bedded, leaf-like in texture, with *Productus muricatus*, *Chonetes mesoloba*, *Derbya crassa* and *Productus costatus*		3
1.	Clay, green	3	

The lower portion of this section, numbers 1 to 7, is seen best on the east side of Clanton creek near Hanley (Tp. 75 N., R. XXVI W., Sec. 22), numbers 1 to 4 being seen only at this place.

Below the limestone ledges quarried north of St. Charles and belonging to the Bethany limestone, beds corresponding to numbers 14–17 of the above section are exposed at the proper horizon. The limestone (numbers 14–16) carries *Productus muricatus* and fragments of fish teeth.

Still farther north on the road leading into St. Charles from the north (South township, section 11) the following beds are exposed in a gully. The section starts 100 feet below the upland.

		Feet.	Inches.
19.	Shale, gray, clayey below, to micaceous sandy above	30	
18.	Limestone, compact, earthy brown, with *Spirifer plano-convexus* (?) and *Spirifer cameratus*	1	
17.	Shale, gray, argillaceous		8
16.	Shale, black, carbonaceous		6
15.	Coal, impure		5
14.	Shale, gray to buff, argillaceous	4	
13.	Coal, impure	3	
12.	Shales, gray, argillaceous	3	
11.	Clay, yellow, ocherous, with *Productus cora*	4	
10.	Limestone, impure, earthy, with *Productus muricatus*	6	
9.	Shales, argillaceous, green below, red above	3	

		FEET.	INCHES.
8.	Limestone, dense, non-fossiliferous		3
7.	Shales, gray to drab, clayey	1	
6.	Shales, black, carbonaceous, with *Productus muricatus*	1	
5.	Limestone, fragmental		2
4.	Shale, gray, clayey	2	
3.	Limestone, similar to number 5	1	6
2.	Shale, gray, clayey	2	
1.	Limestone, soft, yellow, earthy	8	

This section may be correlated, though not closely, with the Hanley section. Number 18 in the present section probably represents number 12 of that; numbers 15 and 11, numbers 13 and 8; numbers 10 and 7, numbers 8 and 5; numbers 6 and 3 and numbers 5 and 2 may be considered as equivalents. The comparison shows well the persistence and the variation in the beds of this portion of the Des Moines.

South of Patterson the exposure along a ravine (Tp. 76 N., R. XXVI W., Sec. 32, Nw. qr., Se. ¼) yields the following section:

		FEET.	INCHES.
14.	Shale, black	2	
13.	Unexposed	21	
12.	Shale, blue, clayey above, gray, sandy below	16	
11	Limestone, dense, drab, fossiliferous	1	
10.	Shale, blue, clayey	3	
9.	Sandstone, gray		5
8.	Shale, clayey, blue and gray	27	
7.	Sandstone, gray, nodular	1	
6.	Shale, sandy, drab	27	
5.	Limestone, arenaceous, gray, fossiliferous		9
4.	Shale, black	2	
3.	Shale, gray, clayey (only partly exposed)	30	
2.	Coal		6
1.	Shale, red (only partly exposed)	32	

The base of this section is on a level with Middle river. The imperfect exposure of some of the beds makes its correlation difficult, but it seems probable that number 1 represents numbers 14–16 of the Hanley section.

Aside from these sections along Clanton creek and its tributaries there are occasional outcrops of Des Moines strata throughout the eastern portion of the county.

North of Tileville is a section which will be discussed later. In Lee and Jefferson townships the strata are quite generally concealed beneath the drift. They seem to consist largely of clayey and sandy shale with some sandstone. About four miles southwest of Boonville (Tp. 77 N., R. XXVIII W., Sec. 11) a two-foot layer of sandstone appears in the hillside 106 feet below the upland. Sixty feet above it is a stratum of gray sandy limestone, about two feet thick and weathering into thin layers. Similar beds may be seen farther down Badger creek in section 12 of Jefferson and sections 20 and 15 of Lee townships. The limestone is thought to be identical with that seen along the Raccoon river and numbered 13 in the following section obtained by Mr. Leonard in Dallas county (Tp. 78 N., R. XXVII W., Sec. 26, Nw. qr., Sw. ¼):

		FEET.	INCHES.
15.	Drift	6+	
14.	Sandstone, soft, gray, with flakes of yellow mica	8	
13.	Shales, sandy, gray	15	
12.	Limestone, sandy, fossiliferous	1	2
11.	Shales, carbonaceous, coaly below	1	4
10.	Shales, gray	4	
9.	Sandstone, heavily bedded with Lepidodendrons	4	
8.	Shale, sandy above	6	
7.	Coal		6
6.	Shales, clayey, variegated	20	
5.	Shales, bituminous	2	
4.	Limestone, fragmentary	5	
3.	Shales, blue to gray	6	
2.	Shales, carbonaceous	2	
1.	Shales, blue, clayey, exposed	5	

Number 7 of this section is considered by Mr. Leonard to be the Marshall coal, and the various members of the section have been recognized along the Raccoon as far west as Guthrie county. In Madison county the limestone and coal are present in Crawford township, sections 17 and 18, and are probably represented in some of the coal horizons noted along Clanton creek. The exact correlation, however, of the

Dallas county and the Clanton creek exposures cannot be made out, and it is doubtful whether the two sections are to be considered as equivalent in other than a general way.

MISSOURIAN FORMATION.

The beds found in Madison county which are referred to the Missourian belong entirely to the lower member, the Bethany limestone. They afford an almost complete section of that member, certain of the higher beds found on Grand river in Union county alone being lacking. The Bethany, as seen here, includes four bodies of limestone separated by shales. The complete section is well exposed on Middle river in Lincoln township, and along a ravine in section 22 the following section, which may be taken as typical, was made out.

		FEET.	INCHES.
20.	Limestone, yellow, earthy, in thin layers, with Fusulina, Aulopora and *Productus semireticulatus*	4	
19.	Shale, drab to yellowish	1	
18.	Alternating calcareous and shaly bands, yellowish, with *Derbya crassa*, *Productus longispinus* and *Spirifer plano-convexus*	3	
17.	Dark shale	2	
16.	Ledge of compact limestone	1	2
15.	Dark blue shale, with many crushed individuals of *Productus longispinus*		6
14.	Black, very carbonaceous shale	1	
13.	Shale, argillaceous above, becoming sandy below	4	6
12.	Limestone, coarse, divided by shaly partings	3	
11.	Shale, dark, in part very carbonaceous, with band crowded with *Chonetes verneuilianus* and with occasional specimens of *Spirifer cameratus* and *Productus cora*. In places the Chonetes are cemented into a thin band of limestone	8	
10.	Blue limestone, very fossiliferous, in three bands separated by shale	3	
9.	Shale, dark above, lighter below	2	
8.	Marly, yellowish shale	3	

		Feet.	Inches.
7.	Yellowish, soft limestone, which becomes harder below	5	
6.	Thin layers of limestone with shaly partings	12	
5.	Black slate and shale	3	
4.	Yellowish, earthy, calcareous beds showing effect of irregular deposition	4	
3.	Limestone, with thin alternating beds of shale	12	
2.	Black shale	3	
1.	Band of limestone		6

At the mouth of the ravine and below number 1 of the above section is a sandy shale about fifteen feet thick shown in the lower portion of figure 75. A short distance up the

[illegible] limestone and underlying beds as seen in section 20 of Lincoln township.

[illegible] locality known as the Devil's Backbone, beds [illegible] enumerated are exposed. Below the [illegible] and forming the ledges over which the [illegible] following:

	FEET.	INCHES.
4. Limestone, thin bedded, weathering into nodular fragments	5	
3. Shale, parting		3
2. Limestone, similar to above	4	
1. Shale, blue to buff, to river	2	

In number 2 of this section *Athyris subtilita* occurs, being small, rather smooth, and with a feebly developed fold and sinus. In number 4 the specimens of Athyris found are larger. In number 2 *Spirifer cameratus*, *Meekella striato-costata* (small) and *Axophyllum rude* also occur.

FIG. 78. The Tunnel mill at the Devil's Backbone. The main body of the limestone over the tunnel is the Earlham. That over which the water falls at the mill is the Fragmental.

The limestone forming numbers 2 and 4 of the section just given occurs at many points in Madison and adjoining counties. It forms the lowermost of the heavy limestones which mark the base of the Missourian formation and is considered to be the basal member of the Bethany. From its general character it is called the Fragmental limestone.

The first heavy limestone above the Fragmental, number 3 of the exposure in section 22, Lincoln township, is the equivalent of the beds quarried at Earlham, and hence may be called

the Earlham limestone. Numbers 6 and 7 are well exposed at Winterset, and have been extensively quarried there, so that the term Winterset, heretofore used loosely as the equivalent of Bethany, may be appropriately restricted to this horizon. Number 20 forms the base of a limestone member attaining in the vicinity a thickness of as much as twenty-five feet, and which from the abundance of Fusulina characterizing it may be called, for the present at least, the Fusulina limestone. The characteristics of these individual beds will be brought out in discussing the various exposures.

The Fragmental limestone is not well exposed in the vicinity of the Earlham quarries, though north of that place on Bear creek, Mr. Leonard has found it with the usual assemblage of fossils. In Guthrie county, just north of Stuart, it is well developed. Along a small stream emptying into Deer creek north of Stuart the basal portion of the Bethany is exposed. The lowest rock seen is the Fragmental limestone, which is made up of irregular bits of limestone filled in with calcareous shale. At one point it can be pulled to pieces with the fingers. At another it is hardened into massive (two feet) ledges. A total thickness of ten feet is seen. The fossils found include the following:

Lophophyllum proliferum.
Archæocidaris, sp.?
Productus longespinus.
Orthis pecosi.
Athyris subtilita.
Hustedia mormoni.
Spirifer lineatus.
Spirifer cameratus.
Bellerophon, sp ?
Straparollus, sp.?

The fauna is much like that found near St. Charles.

The Fragmental rock is seen southwest of Winterset along the ravine leading down to Middle river, but the best exposures are along Clanton creek and around the edges of the St. Charles-Truro upland. About a half mile south of Peru, on

the east side of the Chicago Great Western track, the Fragmental rock in its normal faciès of loosely cemented bits of limestone is exposed twenty-four feet above Clanton creek. It carries abundant *Spirifer lineatus* and *Athyris subtilita* with frequent *Hustedia mormoni.* It is seen at several points in the vicinity, and a total thickness of ten feet is indicated. It is covered by fifteen to seventeen feet of gray shale, over which is found the Earlham limestone and the normal sequence. The rock is seen again just east of Peru in the banks of the creek and along tributaries of the main stream, and has been opened up at several points east of Hanley. At the point north of Truro (section 35, South township, at which the section of Des Moines beds already given is exposed), the Fragmental rock is found capping the Des Moines. It is here two and one-half feet thick, and is not particularly fragmental in character, but carries the following fauna:

Productus costatus.
Productus longispinus.
Athyris subtilita.
Hustedia mormoni.
Spirifer cameratus.
Spirifer lineatus.
Spiriferina kentuckensis.
Rhynchonella (Pugnax) uta.
Dielasma bovidens.
Bellerophon, sp.?
Naticopsis, sp.?

At the quarries north of St. Charles the rock shows the same thickness in ledges of four to six inches. The fossils found there are:

Productus longispinus.
Productus costatus.
Athyris subtilita.
Hustedia mormoni.
Spirifer cameratus.
Spirifer lineatus.
Rynchonella (Pugnax) uta.
Bellerophon, sp.?

	FEET.	INCHES.
7. Yellowish, soft limestone, which becomes harder below	5	
6. Thin layers of limestone with shaly partings	12	
5. Black slate and shale	3	
4. Yellowish, earthy, calcareous beds showing effect of irregular deposition	4	
3. Limestone, with thin alternating beds of shale	12	
2. Black shale	3	
1. Band of limestone		6

At the mouth of the ravine and below number 1 of the above section is a sandy shale about fifteen feet thick shown in the lower portion of figure 75. A short distance up the

FIG 75. The Earlham limestone and underlying beds as seen in section 20 of Lincoln township.

river, at the locality known as the Devil's Backbone, beds equivalent to those enumerated are exposed. Below the shales just mentioned and forming the ledges over which the water falls is the following:

		FEET.	INCHES.
4.	Limestone, thin bedded, weathering into nodular fragments	5	
3.	Shale, parting		3
2.	Limestone, similar to above	4	
1.	Shale, blue to buff, to river	2	

In number 2 of this section *Athyris subtilita* occurs, being small, rather smooth, and with a feebly developed fold and sinus. In number 4 the specimens of Athyris found are larger. In number 2 *Spirifer cameratus*, *Meekella striatocostata* (small) and *Axophyllum rude* also occur.

FIG. 76. The Tunnel mill at the Devil's Backbone. The main body of the limestone over the tunnel is the Earlham. That over which the water falls at the mill is the Fragmental.

The limestone forming numbers 2 and 4 of the section just given occurs at many points in Madison and adjoining counties. It forms the lowermost of the heavy limestones which mark the base of the Missourian formation and is considered to be the basal member of the Bethany. From its general character it is called the Fragmental limestone.

The first heavy limestone above the Fragmental, number 3 of the exposure in section 22, Lincoln township, is the equivalent of the beds quarried at Earlham, and hence may be called

the Earlham limestone. Numbers 6 and 7 are well exposed at Winterset, and have been extensively quarried there, so that the term Winterset, heretofore used loosely as the equivalent of Bethany, may be appropriately restricted to this horizon. Number 20 forms the base of a limestone member attaining in the vicinity a thickness of as much as twenty-five feet, and which from the abundance of Fusulina characterizing it may be called, for the present at least, the Fusulina limestone. The characteristics of these individual beds will be brought out in discussing the various exposures.

The Fragmental limestone is not well exposed in the vicinity of the Earlham quarries, though north of that place on Bear creek, Mr. Leonard has found it with the usual assemblage of fossils. In Guthrie county, just north of Stuart, it is well developed. Along a small stream emptying into Deer creek north of Stuart the basal portion of the Bethany is exposed. The lowest rock seen is the Fragmental limestone, which is made up of irregular bits of limestone filled in with calcareous shale. At one point it can be pulled to pieces with the fingers. At another it is hardened into massive (two feet) ledges. A total thickness of ten feet is seen. The fossils found include the following:

Lophophyllum proliferum.
Archæocidaris, sp.?
Productus longespinus.
Orthis pecosi.
Athyris subtilita.
Hustedia mormoni.
Spirifer lineatus.
Spirifer cameratus.
Bellerophon, sp.?
Straparollus, sp.?

The fauna is much like that found near St. Charles.

The Fragmental rock is seen southwest of Winterset along the ravine leading down to Middle river, but the best exposures are along Clanton creek and around the edges of the St. Charles-Truro upland. About a half mile south of Peru, on

the east side of the Chicago Great Western track, the Fragmental rock in its normal faciès of loosely cemented bits of limestone is exposed twenty-four feet above Clanton creek. It carries abundant *Spirifer lineatus* and *Athyris subtilita* with frequent *Hustedia mormoni.* It is seen at several points in the vicinity, and a total thickness of ten feet is indicated. It is covered by fifteen to seventeen feet of gray shale, over which is found the Earlham limestone and the normal sequence. The rock is seen again just east of Peru in the banks of the creek and along tributaries of the main stream, and has been opened up at several points east of Hanley. At the point north of Truro (section 35, South township, at which the section of Des Moines beds already given is exposed), the Fragmental rock is found capping the Des Moines. It is here two and one-half feet thick, and is not particularly fragmental in character, but carries the following fauna:

Productus costatus.
Productus longispinus.
Athyris subtilita.
Hustedia mormoni.
Spirifer cameratus.
Spirifer lineatus.
Spiriferina kentuckensis.
Rhynchonella (Pugnax) uta.
Dielasma bovidens.
Bellerophon, sp.?
Naticopsis, sp.?

At the quarries north of St. Charles the rock shows the same thickness in ledges of four to six inches. The fossils found there are:

Productus longispinus.
Productus costatus.
Athyris subtilita.
Hustedia mormoni.
Spirifer cameratus.
Spirifer lineatus.
Rynchonella (Pugnax) uta.
Bellerophon, sp.?

Naticopsis altonensis.
Straparollus catilloides.
Straparollus, sp.?

The same bed is seen southeast of St. Charles (section 1, Ohio township), and on South river (section 28). At each locality the usual assemblage of fossils, characterized by the great abundance of small, smooth specimens of *Spirifer lineatus* and *Athyris subtilita* and the comparatively rare occurrence of *Spirifer cameratus* and *Productus costatus*, was found. The fauna is one of the most characteristic, both in species, character, and relative abundance of forms found in the region, and makes an excellent guide for tracing the base of the Missourian. Near Truro and St. Charles there are no good exposures of the higher limestone, though their presence is indicated. On South river the exposures show the following section.

	FEET.	INCHES.
6. Limestone, thin bedded with *Productus cora*, and *Athyris subtilita* (large)	2	6
5. Unexposed	6	
4. Limestone, fragmental in part, with *Spirifer lineatus*, *Athyris subtilita* (small) *Rynchonella uta*, *Hustedia mormoni*, etc.	3	
3. Shale, argillaceous drab to black	3	
2. Unexposed	10	
1. Sandstone, yellow, with ripple marks and heavy cross-bedding	6	

Number 6 of this section probably represents the Earlham. More limestone seems to be present in the hills, but is not exposed.

The Earlham limestone is best exposed in the quarries near the town of that name. At the Robertson quarry, two miles east of Earlham, the following section was noted:

	FEET.	INCHES.
11. Bed of soft, yellowish, magnesian, earthy limestone, decomposing readily when exposed to weather	4	
10. Limestone in three heavy ledges at west end of quarry	4	
9. Buff shale with *Chonetes verneuilianus*		4
8. Limestone, like number 4	2	

		FEET.	INCHES.
7.	Ashen shale with very few fragments of brachiopod shells		6
6.	Earthy limestone, decomposing readily, yellowish, carrying large individuals of *Athyris subtilita*		3
5.	Drab shale, with *Productus longispinus*, *P. costatus*, crinoid stems and fragments of other fossils		6
4.	Quarry limestone, in thin layers, irregularly bedded	8	
3.	Unexposed	20	
2.	Sandstone, in heavy layers	7	
1	Base of sandstone to creek, unexposed	17	

At one point the quarrymen had worked down in the bottom of the quarry and exposed, below number 4, drab and black shales to the depth of three feet, and below the shales a ledge of limestone six inches in thickness.

Distributed through the limestone beds number 4 are the following:

Lophophyllum proliferum McChesney.
Stem segments and body plates of crinoids.
Various species of Bryozoa.
Meekella striatocostata Cox.
Productus punctatus Martin.
P. costatus Sowerby.
P. longispinus Sowerby.
P. cora D'Orbigny = *P. pattenianus* of authors.
Athyris (*Seminula*) *subtilita* Hall.
Hustedia mormoni Marcou.
Spirifer cameratus Morton.
Spiriferina kentuckensis Shum.
Allorisma subcuneatum M. & H.

Chonetes verneuilianus N. & P. is somewhat common in number 9 but is very rare in the other members of the section. *Spirifer cameratus* and *Productus longispinus* are most abundant near the base of number 4, while *Productus costatus* and *Athyris subtilita* are more common in the upper layers. All the species enumerated, however, with the exception of *Allorisma subcuneatum*, range through all the beds making up number 4.

At the quarries south of Earlham in section 18, Madison township, the beds from 4 to 11 inclusive of the Robertson quarry section are exposed and are overlain by blue, drab and buff shales eight feet in thickness. The beds here carry the same fauna as the corresponding beds at the Robertson quarry.

North of Winterset the beds making up the sections seen in the quarries near Earlham are exposed along Cedar creek in section 25 of Douglass township. The beds rest on the black shale seen beneath number 4 at Robertson's quarry. The entire section is as follows:

	FEET.	INCHES.
8. Limestone, in heavy ledges	4	
7. Shale, buff, with very abundant *Chonetes verneulianus*		4
6. Limestone, heavy bed	2	
5. Shale, blue, with a thin bed of reddish decomposing limestone carrying large *Athyris subtilita*		8
4. Limestone, thin bedded quarry rock	8	
3. Shale, drab to black	2	
2. Limestone, dense black	1	
1. Shale, drab	4	

Equivalent beds may be seen at several points between Earlham and Winterset. At the latter place the Earlham rock is exposed near the old lime kiln southeast of town. Along the ravine running down to Middle river the completed section is as follows:

	FEET.	INCHES.
26. Limestone, blue, Meekella zone		4
25. Shale, drab to yellow	3	
24. Limestone, blue, three thin ledges separated by shale, *Chonetes verneulianus* very abundant	1	
23. Shale, drab	1	3
22. Limestone, blue		4
21. Shale, drab, with very many specimens of *Derbya crassa* in and just below the limestone	4	
20. Limestone, earthy magnesian, easily disintegrating	5	
19. Shale, drab	4	

		Feet.	Inches.
18.	Limestone, medium grained, coarse bedded, quarry rock	12	
17.	Shale, clayey, drab	2	
16.	Shale, black, slaty	1	
15.	Shale, drab	4	
14.	Limestone, soft, earthy	6	
13.	Limestone, nodular, irregularly bedded	4	
12.	Shale, yellow		6
11.	Limestone, nodular	4	
10.	Limestone, thin bedded with *P. oductus cora*, *Meekella striatocostata*, *Athyris subtilita*	10	
9.	Shale, blue to drab	1	
8	Shale, black, slaty	1	6
7.	Limestone, black, impure		6
6	Shale, gray, clayey to sandy	15	
5.	Limestone, fragmental	3	
4.	Unexposed	6–8	
3	Shale, gray, clayey	1	
2.	Unexposed	3	
1.	Limestone, fragmental	3	

Of the above section numbers 1 to 5 may be referred to the Fragmental limestone. Number 10 represents the Earlham. Number 18, which has been quarried at the edge of town, the quarries being west of and above the lime kiln quarry, represents the Winterset. There is a slight dip to the west here which is at first deceptive.

The Earlham beds are seen southwest of Winterset below the old Court House quarries (section 12, Lincoln township) and again at the Backbone, where they form the heavy bed of rock above the tunnel. At this point the member attains a thickness of twenty-one feet. The thin band of shale carrying *Chonetes verneulianus* and the underlying black slate and black limestone are excellently developed. The beds are also seen along Clanton creek.

The Winterset limestone has been noted in describing the preceding sections. It is best exposed in and near Winterset and along Middle river southwest of the county seat. The beds above it and below the Fusulina limestone are of particular interest because of the abundance and perfection of the

length of the individuals under consideration is about the same as that of average specimens from Montgomery county and other localities where the normal condition prevails, but the diameter is less than half that of average specimens in southwestern Iowa. Farther west, in Nebraska and neighboring states and at a slightly higher horizon, the form described as *Fusulina ventricosa* occurs. The forms at Winterset constitute an interesting term in the series showing that this Carboniferous Foraminifer, after its introduction in the lower part of the Missourian stage, became progressively more and more robust until its disappearance in the so-called Permo-Carboniferous of Nebraska and Kansas. The Fusulina limestone at the Backbone shows the following:

		FEET.
3.	Limestone, with many Fusulina	2
2.	Limestone, thin bedded	13
1.	Limestone, massive ledge very full of Fusulina	3

At some points in the vicinity this member attains a thickness of twenty-five feet. The lower ledge especially seems to be very constant in character, and the great abundance of the Fusulina here as compared with their number in the lower members of the Bethany makes the bed easily recognized.

As has already been suggested the upper portions of the Bethany are not exposed over the eastern portion of the county. At Tileville (Tp. 76 N., R. XXVII W., Sec. 27, Ne. qr., Sw. ¼), in a ravine running down to Cedar creek, the lower portion of the Bethany is shown as given in the following section.

		FEET.	INCHES.
14.	Limestone, shaly, gray	8	
13.	Unexposed	6	
12.	Limestone, in thin layers	4	
11.	Shale, clayey	5	
10.	Limestone, bluish, dense	1	2
9.	Shale, clayey, in places sandy	1	2
8.	Sandstone, calcareous		4
7.	Shale, clayey, dark blue	2	3
6.	Coal		1
5.	Shale, clayey	3	
4.	Shale, red and yellow	1	6
3.	Shale, sandy, gray, with reddish layer	24	
2.	Sandstone, calcareous	2	3
1.	Not exposed to Cedar creek	57	

The limestones numbers 12 and 10 probably represent the base of the Bethany. They are not particularly fossiliferous and the whole section is slightly out of harmony with the stratigraphy of the neighborhood. The lack of good exposures for the present prevents the tracing of the beds to their equivalents.

PLEISTOCENE DEPOSITS.

Over the limestones of the Missourian and the shales and sandstone of the Des Moines are the bowlder clays, sands and loess deposits which mark the action of the Pleistocene glaciers. The most notable fact with reference to these beds, as compared with the corresponding deposits of the neighboring regions, is their exceptional thinness. There are regions of thick drift, but they are unusual, particularly in the western and northwestern portion of the county, where the thinness of the drift becomes striking. In some portions of the county, as near Winterset, and between that point and Peru, the topography is strikingly like that of a driftless area. The same is true to a less extent of the region between Winterset and Earlham. The level divides, the canyon-like valleys, and the absence of the long, gentle slopes so common in the drift-covered regions, all recall, in their general aspect, the areas from which drift is absent. The frequent and abundant presence of residual clays tends to heighten the delusion. In the quarries at Earlham, and to an almost equal extent at Winterset, such clays are quite common. The red to reddish brown sticky clay which has resulted from the secular decay of the limestone, is found penetrating far down into the joint cracks and resting upon the upper surface of the rock. When shale forms the upper member of the rock series, the residual material is not so noticeable, though disintegrated shale, grading on the one hand into drift, and on the other into the undecomposed and undisturbed material, may be noted in the quarries of the Earlham Land Co. and at other points. The presence of the geest and undisturbed shale attest the feebleness of the glacial action. The ice crept in over the country,

with almost no scouring effect. In contrast with its behavior in some other portions of the country it produced here very little erosion. Its action was rather that of deposition. Nevertheless, in the deeper, sharp-walled valleys which the glaciers crossed, there seems to have been comparatively little drift deposited. Probably the relative narrowness of the valleys, their abrupt walls, and their position approximately at right angles to the major motion of the glaciers, caused them to be filled with comparatively stationary ice, while the main ice stream passed over their tops.

The deposits within the county include representatives of the Kansan drift, the loess and the alluvium. While the older Albertan or Sub-Aftonian ice sheet probably crossed the county, the deposits left by it have not so far been recognized.

KANSAN DRIFT.

The Kansan drift is quite generally distributed throughout the county and is exposed along most of the streams. The lower part consists of a compact blue clay with small water-worn and flattened pebbles scattered through it. Where the ravines have been cut down into this clay these pebbles have often worn pot-holes, giving the otherwise smooth and rounded exposures a pitted appearance. This lower clay is best seen in the southeastern part of the county, especially southeast of Truro.

Above the blue clay is a yellowish brown layer usually two to four feet thick. In places it is much thicker. It seems to have been derived from the blue clay, the change in color resulting from the oxidation of the iron content. The clay contains numerous pebbles and bowlders. The latter consist largely of greenstone, granite and reddish quartzite, and lighter quartz rocks. These are rounded, smoothed and often well striated. Sioux quartzite is one of the most common rocks found in the drift. A block of this material is represented in figure 78. This bowlder is located a mile north of Patterson and measures ten feet long, six feet wide and five feet high,

as exposed. Such large bowlders are uncommon, but are occasionally found in the stream ways. Bowlders ordinarily are not found on the upland. It is only where the streams have cut through the loess that they appear.

Stratified sandy material is occasionally found in the drift. In general it seems to have resulted from the reworking of the drift itself, rather than to have been originally deposited in its present form. Such beds are found near Barney (Walnut township, section 35) thirty-five feet thick. Near Macks-

FIG. 78. Surface bowlder one mile south of Patterson (Tp. 76 N., R. XXVI W., sec. 20, Se. qr., Sw. ¼). The rock is red quartzite, 10 feet long, 6 feet wide, and 5 feet above ground. It is said to extend 5 feet into the ground.

burg, on Grand river (Tp. 74 N., R. XXIX W., Sec. 28, Nw. qr., Nw. ¼) there is a thirty foot exposure of the same material.

LOESS.

The loess is the surface deposit throughout the county. It spreads over upland and extends down into the valleys. It is everywhere present except where it has been cut away by recent erosion or buried beneath the alluvium. It is a light yellowish to buff, unstratified, pebbleless clay, which is highly

siliceous. Where it forms the surface the upper few inches are blackened by the admixture of humus. Elsewhere the buff color obtains. It frequently contains the calcareous concretions known as loess-kindchen.

There are two phases of the loess in the county. The upper is the one just described. Below it is frequently a darker portion, more clayey, less porous and, as contrasted with the upper, unfosiliferous. So far as observed this lower loess is characteristically free from lime nodules. In the northwestern portion of the county it forms the subsoil and is in places troublesome because of its impervious character. The two phases may be seen at the Mardis brickyard, a mile east of Winterset (Tp. 76 N., R. XXVII W., Sec. 32), and the line of separation seems to be properly correlated with the old soil seen in the railway cut at Churchville. A similar division of the loess into two phases has been observed in Warren county.* It is to be noted that the lower portion corresponds in character to the white clays of Ohio as described by Leverett, and the two phases may not improbably stand for a real and considerable difference in the age of the deposits.

ALLUVIUM.

Alluvium is present along most of the streams of the region, but is most pronounced along the larger ones. It lies as a wash over the loess and drift which partially fills the old valleys, and in places attains a considerable thickness. West of the Winterset escarpment it is not so clayey as east of that line. Its greatest development is in the broader valleys cut in the Des Moines shales and coal measures. Along Middle river, south and west of Winterset, there is a well defined terrace rising eighteen feet above the flood plain. This seems to be an older flood plain or terrace of aggregation. Traces of similar terraces are found along certain of the other streams in the county.

*Iowa Geol. Surv., vol. V, pp. 318-356. 1896.

ECONOMIC PRODUCTS.

Building Stones.

Madison county is well supplied with stone suitable for various constructional purposes. The Bethany limestone includes nearly eighty feet of stone, most of which is available for one purpose or another. It is exposed in the ravines over much of the county and good quarry sites abound. As a rule but little stripping is required.

As will be seen from the general section already given there are four main bodies of limestone, designated respectively from the base to the top: (a) Fragmental, (b) Earlham, (c) Winterset quarry, (d) Fusulina. The general distribution of these beds has been already noted. Their varying thickness may be learned from the sections given. In general it may be said that they are thicker to the southwest. Some instances of their variation in this particular have been given. Each of the four members is capable of yielding good quarry rock at some point in the county, but not all are equally good at all points.

The Fragmental rock is best seen, and is exposed in its greatest thickness, at the Backbone mill, where it forms the ledge over which the water falls. At this point about nine feet of the rock is shown with only one important shale parting. The rock seems firm and should yield large blocks, but in view of its known character elsewhere in the county it is to be received with suspicion. In general the rock is very loosely cemented and breaks down readily into small nodular fragments.

The Earlham ledges are the most quarried. They yield a good grade of stone suitable for dimension work, rubble and concrete. When quarried, the Earlham is usually unprotected by overlying ledges and hence has been long exposed to weathering. As a result it is frequently badly broken up and creates a less favorable impression than the real merits of the stone warrant.

The Winterset quarry beds include those worked near Winterset and from which the stone used in the court house at that point was obtained. Their high quality is sufficiently attested by the excellent appearance of that building. The rock here used was taken from the Bevington quarry (Tp. 75 N., R. XXVIII W., Sec. 22), and certain of the layers tested at the Rock Island arsenal in 1881 showed a crushing strength of 4,588 pounds per square inch. The specific gravity of the rock was 2.73 and the ratio of absorption .042603. Stone from these beds rarely reaches the market at present, as the quarries have not been opened up except at Winterset and it requires a long haul over hilly roads to reach the railway at this place.

The Fusulina limestone is best exposed at the Backbone and seems capable of yielding excellent stone. At this locality compact ledges two and one-half to three feet in thickness may be obtained. Farther southwest the member attains a thickness of twenty-five to thirty feet. At Peru in the Reed quarry about fifteen feet are found. The stone here is thinner bedded than in the western outcrops.

In the main the quarry industry is concentrated around three points, Earlham, Winterset and Peru. The first has the advantage of location on the main line of the Chicago, Rock Island & Pacific railway, with a down grade haul of about thirty miles to Des Moines. As a result considerable quantities of stone, mainly crushed for concrete work, are marketed in the capital city. Winterset, on a branch line of the same road, is farther from market and suffers the disadvantage of less favorable freight rates. The quarries now open near this city are not so well located for connecting with the railway as at Earlham, but if the projected road southwest from Winterset be built, many excellent quarry sites will become available, and a large amount of stone can be placed on the market. At Peru and Barney the quarries are located near the Chicago Great Western but have no track facilities, so that a short wagon haul is necessary. The stone now quarried at Peru is so high in the

bluffs, seventy-four feet above the station, that a track to the quarries would not be practicable. The lower (Earlham) ledges occur not far above the level of the track, but to open them up it would be necessary to work out the overlying ledges as well. This would require considerable stripping and the handling of all the shales between the various ledges. It is doubtful whether such work would pay, certainly not without ample capital and an extensive plant. For the present only the best ledges can be marketed, as the poorer stone will not warrant the wagon haul and must be thrown on the dumps.

At Barney the Great Western track is more than fifty feet higher than at Peru, and west of there it ascends to the top of the bluff. About two miles east of Barney the Winterset rock has been cut through by the road, and in the bank of Clanton creek the Earlham layers are exposed. Quarries could be opened here with the minimum of track expense and with very little stripping. While the rock exposed is not to any great extent suitable for dimension stone it is excellently adapted for concrete, and a considerable amount of rubble could be obtained. Some dimension rock is exposed, and it seems probable that the Winterset beds, which are mainly talus-covered, would warrant opening.

EARLHAM DISTRICT.

Robertson quarry.—When the state capitol was being built at Des Moines the limestone around Earlham was opened up at a number of points. The principal of these old quarries was located northeast of Earlham on Bear creek. They have long since been abandoned, and ledges nearer the main line of the Chicago, Rock Island & Pacific railway are now worked. The rock as seen in some of the older workings on the north side is shown in plate ix. The main quarrying is now, however, carried on on the south side.

A section near the middle of the quarry shows the following:

		FEET.	INCHES.
9.	Stripping	10	
8.	Limestone, soft, disintegrated, with geest in the crevices	4	

EARLHAM LIMESTONE IN OLD QUARRIES NORTH OF THE RAILWAY.

		FEET.	INCHES.
7.	Limestone, compact, massive, bluish	1	6
6.	Shale, drab, calcareous		4
5.	Limestone, compact, bluish, in thin ledges	3	
4.	Shale, bluish, with very many *Chonetes verneulianus*		4
3.	Limestone, compact, blue	2	
2.	Shale, blue, calcareous	1	
1.	Limestone, ashen, thick to thin layers	10	

But little dimension rock is taken from the quarry. Some of the stone is used for foundation and retaining walls, but

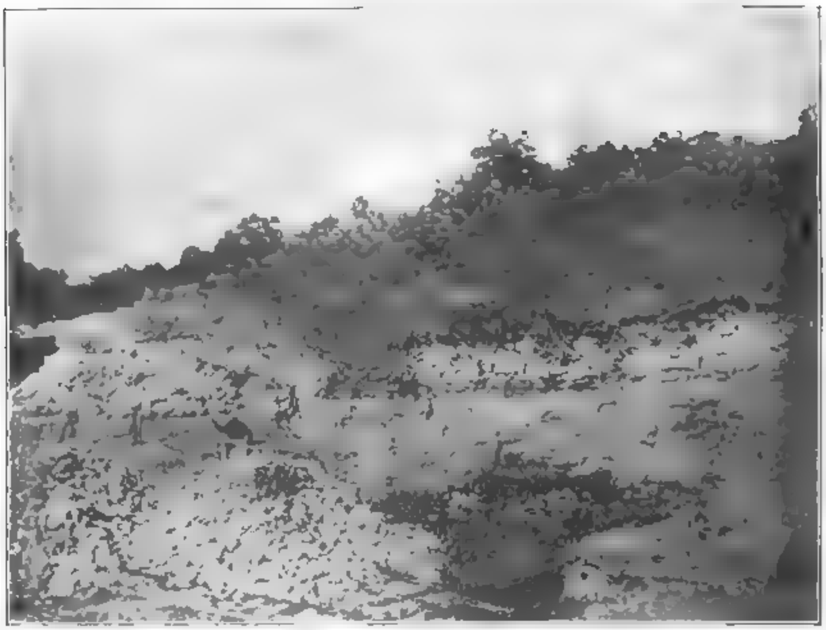


FIG. 79. A portion of the Robertson quarry east of Earlham, showing a typical exposure of Earlham limestone.

most of it is crushed. The stripping is done by hand. Very little blasting is necessary to loosen the rock. The stone is hauled to the crusher in tram cars of about one cubic yard capacity, and hoisted and dumped by tail rope. The plant includes a forty-horse power steam plant, one Gates crusher, elevator and revolving screen. The screen takes out all

material less than three-eighths inches in diameter, the fine material being used by the railway for yard filling at Valley Junction. The coarser rock is used mainly for concrete at Des Moines, and brings $1.30 per yard. The plant has a capacity of about 200 yards per day.

Earlham Land Co.—The quarries of this company are located south of town, in the valley of North river, and are illustrated in plate x. As has already been stated, the beds opened up are the equivalents of those found at the Robertson quarry. There is, however, an overlying shale not found at the latter place.

The rock is cut by a series of joints, some of which have spread till there is an open space of as much as seven inches. These crevices are sometimes filled by stalactitic matter, which usually coats merely the sides, but in places the crevices are completely filled. The presence of the joints and bedding planes makes the quarrying easy, and very little powder is used. As at the Robertson quarry most of the rock is crushed, though some good dimension stone could be obtained. The crushing plant includes a Gates crusher, tail rope, screens and steam plant. The capacity is 150 to 200 cubic yards per day, and the quarry employs about thirty men. The output is shipped on a switch from the Chicago, Rock Island & Pacific railway.

Nevitt quarry.—This is a local quarry opened some years since a mile southeast of Earlham. It supplies an important local trade.

Eureka quarry.—This quarry, formerly known as the McGorrisk, is a mile and a half south of Earlham (Tp. 77 N., R. XXIX W., Sec. 18, Nw. qr., Se. ¼). It is not worked at present.

WINTERSET DISTRICT.

There are numerous quarries in and near Winterset, though none are very extensively worked at present. The Clark quarry north of town (Tp. 76 N., R. XXVIII W., Sec. 25), is opened in the Earlham beds. In the southeastern portion of

QUARRY AND CRUSHER OF THE EARLHAM LAND CO.

the city both the Winterset and the Earlham beds have been opened up. In the city quarries the former ledges show about fifteen feet of rock. The lower courses may be used for dressed stone, though they are not easily quarried nor are they generally worked. Good rubble and crushing stone is abundant. On the Arnold place the Earlham stone has been opened up, and was for some years burned into lime at the Cooley kiln. South of Winterset the Brown quarry (Tp. 75 N., R. XXVIII W., Sec. 1, Sw. qr., Se. ¼) was reopened in 1893, and has since furnished considerable curbing stone. The old Kipp quarry, near by, is not now worked. Extensive quarries were formerly worked in the Winterset beds about a mile farther south (Tp. 75 N., R. XXVIII W., Sec. 12, Nw. qr.). It was from these quarries that a portion of the stone for the court house was taken. The pillars and much of the cut stone came from the Backbone quarries (Tp. 75 N., R. XXVIII W., Sec. 16, Ne. qr., Se. ¼). The section at this point has already been given in connection with the description of the limestone.

At the Backbone the heavy ledge at the base of the Fusulina limestone is well shown. It is known to the quarrymen as the magnesian ledge, though several different ledges in various parts of the county are confused under that term. It yields an excellent grade of stone. Higher portions of the Fusulina limestone are exposed in sections 22 and 23 of Webster township. It seems probable that the Fusulina stone, when properly opened up, will be found to yield some of the best rock in the county.

PERU DISTRICT.

In the tops of the hills at Peru the Fusulina rock crops out and is quarried at several points on the west side of the stream. At the Reed quarry from ten to fifteen feet of stone are found, it being for the most part fine-grained and breaking with a conchoidal fracture. The lower portion, four to five feet thick, is heavily bedded and shows some twelve to four-

teen-inch stone. Above this heavy stone is a six-inch bed of shale over which is a thinner bedded, much jointed rock. It furnishes four, six, eight and some twelve-inch stone. Some of the rock is fine-grained and of almost lithographic texture, but is too much cracked and seamed to be of value for dimension work.

The lower beds, including the Winterset, Earlham and Fragmental, have not been opened up, though they show in the hills. About two miles east of Barney the Winterset rock has been cut into by the railway, though the ledges are now largely covered with talus. The blocks exposed show thicknesses of six and eight inches. Below the limestone (1,020 A. T.) the usual black shale is exposed. Along the creek near by, at the proper level below this shale, the Earlham beds are shown and exhibit the following section:

	FEET.	INCHES.
4. Limestone, thin, shaly, grading into calcareous shales	4	
3. Limestone, coarse, made up of shell fragments, rather heavily bedded, ranges up to fourteen-inch rock, good quality	5	
2. Shale, calcareous, gray, *Chonetes verneulianus* abundant, *Spirifer cameratus* rare		6
1. Limestone, thin and irregularly bedded, ledges of six inches and less, stone apparently argillaceous, with dull earthy fracture; carries *Chonetes verneulianus*, *Spirifer cameratus*, *Productus nebrascensis*, *Productus costatus*, *Productus cora*, *Athyris subtilita*, *Meekella striatacostata* and corals; ledges capped by a ten-inch layer of coarse gray rock made up of finely comminuted shells	6	

The only quarry in the vicinity is that of Mr. Irains, where about five feet of stone suitable for dimension work is obtained with very little stripping. In Mr. Irains' house, built of the product of this quarry, the good qualities of the stone may be seen.

ST. CHARLES–TRURO DISTRICT.

Near St. Charles the thin ledges of the Fragmental rock already described are quarried locally. The total thickness of stone is about two and one half feet, the ledges running from four to six inches. Thicker ledges probably occur higher in the hill, but have not been opened up. The quarries at St. Charles marketed last year about thirty perch of stone at 75 cents a perch. Equivalent ledges have been opened southwest of St. Charles.

Road Material.

The matter of good roads is deservedly attracting attention within the county. The considerable portion of the area not reached by railway lines makes wagon hauling more than usually important. To reach a market or to go to the county seat, requires in many cases a drive of ten to twenty miles. A portion of this drive is almost certain to be over very rough roads. The distribution of the drainage and the resultant configuration of the topography causes the north and south roads of the eastern and central portion of the county to be necessarily rough. The considerable relief and the flat topography of the uplands make steep grades at the river crossings almost unavoidable. The grades could be much bettered if the roads had been located with reference to the topography rather than the land lines, but here, as was usual in the Mississippi valley, the necessity for wholesale methods in the rapid settling of the country made deliberation impossible, and it must be the work of the future to correct some, at least, of the mistakes of the past.

The east-west roads chancing to follow drainage lines or the interdigitate divides, have in the main avoided steep grades. Some of the principal lines of travel are, so far as this factor is concerned, excellently located. The north-south roads of the extreme western portion of the county have also, in general, relatively few steep grades. It is not, however, altogether a matter of grades that is provoking here, as else-

where, a good roads agitation. The character of the roadway, be the grade ever so good, may be, and often is, so bad as to make the road quite impracticable at certain seasons. During good weather the roads are beaten hard, and in time are worn smooth; but in the spring, when the frost leaves the ground, many of the roads can be traversed only with the lightest loads. This condition obtains on some of the poorer roads almost the year round. The stiff undersoil of the loess on the uplands, the blue clay of the till, the geest, and much of the alluvium, all of which enter largely into the material forming the surface of the roadways, are predominantly impervious. They are usually, also, notably plastic. They prevent free drainage, and yet form a surface of black, sticky mud which adds greatly to the traction.

The improvement of the roads will necessitate, aside from the matter of location, adequate drainage and surfacing with road metal. More care in the building of the roadways so as to provide the necessary drainage is perhaps the first requisite. For road material the main reliance must be the limestone. Gravel beds of any importance have not been found in the county and probably do not occur, since the Wisconsin, the main gravel-forming ice sheet, did not reach so far south as either to enter the county or cross the headwaters of its streams. The earlier gravel-forming period which followed the pre-Kansan drift has left no traces in the county so far as can be discovered. The streams have not, by their own work, accumulated gravel beds to any considerable extent.

Limestone, however, occurs abundantly throughout most of the county. Some of the worst roads are along the foot of limestone cliffs. Rock could be obtained along most of the main roads readily and cheaply. It has already been used to a limited extent with excellent results. It is crushed in large quantities for the Des Moines market, being used for concrete, and is excellently adapted for macadam.

In stone for macadam two qualities are important: First, it must be sufficiently hard to resist too great wear, and Second,

it must be of such a nature that it will cement rapidly. The matter of hardness is relative only. Rock used in pavements exposed to continuous wear under heavy loads, must be able to resist considerable crushing strains; but for country roads, where the wear is relatively slight, this factor is of less importance. The limestone of the county, while it will of course crush under the wheels and will ultimately wear out, is not apt to prove particularly troublesome in that regard.

A macadam pavement derives its good qualities from the fact that the stone, under the roller or the wheels of traffic, breaks up and yields a fine dust, which with water forms a cement, binding the whole together. In effect a macadam pavement is a cheap concrete in which the bond is derived from the finer portions of the crushed rock. Not all stone, not even all limestone, will furnish a dust which has the requisite cementing properties. In some cases it has proven necessary to cover a macadam roadway with a thin surface of crushed iron or other material in order that the whole should be made to set. The limestone found in Madison county needs no such surface material. It is quite pure and dissolves under the action of surface water with relative rapidity. The dissolved material is frequently redeposited, not far from the point of solution, in the form of stalactitic matter. As was noted in the description of the quarry of the Earlham Land Co., this redeposition is locally important. The redeposited stalactitic matter forms a firm cement, holding together any pieces of rock which may be imbedded in it. Upon the roadway an analogous process takes place, and under proper conditions the recemented rock will form a firm and durable pavement.

The amount of stone necessary for covering a roadway will vary somewhat with the conditions as to foundation, grade, traffic, etc. Upon a properly drained and rolled foundation six inches of stone should be ample for most of the roads of the county. Upon this basis about 1,500 yards per mile would be necessary for a roadway fifteen feet wide. Stone is now being

furnished in Des Moines at $1.30 per yard, but this price could be very materially lessened in case the county crushed its own stone. The expense of grading and rolling the foundation, with that of delivering and spreading the stone would vary with the locality. In New Jersey certain roads are costing about $3,000 per mile. It is probable that the main roads of Madison county could be improved at an average amount considerably less than that sum; perhaps $1,000 to $1,500 could be taken as a fair estimate. To obtain the best results the work would need to be carried on according to a systematic plan, so that the work done each year should be a permanent improvement—a part of a single larger piece of work. The road work now carried on is essentially of a makeshift character. If to the amount of the road tax now annually expended were to be added the aggregate cost of breakdowns, undue wear on horses and vehicles, loss of time due from the light loads hauled, and losses due to inability to market produce rapidly when prices are most favorable, the relative cost of present and improved roadways would appear in the reverse of their present order.

Lime.

The limerock found in the county can be burned to a lime, but the quality of the latter is not of the best. Curiously enough it is not the purest limestones which make the best lime, but those which contain a certain percentage of magnesia—the dolomites and magnesian limestones. For the most part the limestones of the county contain little magnesia. The lime formed from it is white, but is quick and heats rapidly. In slacking it must be handled very carefully and an abundance of water kept on hands. Lime was formerly burned at Winterset, Peru, in section 32 of Jefferson township, and section 9 of Madison township. At present there are no kilns in operation, and it is quite unlikely that kilns will ever be established except for local trade.

Clays.

The abundance of stone and the nearness of the large brick works at Van Meter and Des Moines have prevented the development of any important clay industry in the county. The loess, which is everywhere present, and most of the alluvium found along the streams could easily and cheaply be made up into standard building brick. Only the simplest processes, those of the hand yard, would be necessary. Much of the loess could be made to yield better grades, including stock and face brick, if treated either as a stiff-mud or on a dry-press. In the eastern portion of the county where the Des Moines formation crops out, shales suitable for a considerable variety of products occur. So far they have not been utilized, the only brick now manufactured in the county being made from top soil and loess.

At Winterset there are two brickyards, both without machinery. The T. F. Mardis yard is one mile east of town (Tp. 76 N., R. XXVI W., Sec. 32). Two kilns of 100,000 to 150,000 capacity are ordinarily burned each season. In addition to brick of the usual size, brick twelve inches long are turned out. Southwest of town (Tp. 75 N., R. XXVIII W., Sec. 1) is the brickyard of W. D. and Joel Clark. They maintain two up-draft kilns of 25,000 capacity each for burning brick. At Earlham small quantities of hand-made brick have been made from the loess.

The wide distribution of the loess and the ease with which it can be worked up into brick and draintile upon the inexpensive auger machines, would seem to warrant investment in a plant. The stronger under loess which has given trouble in the hand yards will be found excellently adapted to the manufacture of drain tile, though it must not be dried too rapidly.

Water Supply.

The numerous streams throughout the county adapt it excellently to stock farming. When water is needed for household or industrial purposes it is usually obtained from

wells at shallow depths. The base of the loess and the base of the drift are common water horizons. Water may, however, be found in gravel pockets at almost any level in the drift. The different shale horizons in the Missourian usually furnish water and their outcrops are marked often by lines of springs or water seepage. Water, though not usually of the best quality, is readily obtained from the Des Moines beds. In Jefferson township (section 36) Mr. C. D. Fletcher has a well 268 feet deep ending in a sandstone that lies near the base of the Des Moines. The following analysis of the water, by Dr. Floyd Davis, is published by the courtesy of Mr. Fletcher.

Total solids	5,580
Loss on ignition	1,800
Chlorine	497.5
Free ammonia	1.76
Albumenoid ammonia	Trace
Nitrogen in nitrites	None
Nitrogen in nitrates	None

"These results show that this is a highly mineralized water. The salts in it are principally sodium chloride (common salt). There are no poisonous substances in it. The salts present are really beneficial constituents of a mineral water; the commoner salt acting as a mild tonic, and the glauber salts as a strong cathartic. The sanitary analysis shows that this water is almost entirely free of organic matter, such as might come from drainage, and there are no reasons whatever why this is not a good water for domestic use and for stock."

Water Power.

The rapid fall of the large streams of the county where they cross the Bethany limestones affords many excellent water powers, few of which are at present utilized. In former days there were several mills, the most famous, perhaps, being the tunnel mill at the Backbone. At this point, by means of a tunnel a few hundred feet long, water is

drawn from the river above the Backbone and a head of nearly twelve feet obtained.

North river Middle river, Clanton creek, and many minor streams cross the Bethany limestone. In each case there is a total fall of about eighty feet. This is distributed somewhat, but as each of the four benches of limestone is crossed there is usually a fall of ten to twenty or even more feet. Such water power may well become quite valuable, and it is not improbable that the future will see an important milling industry founded on it.

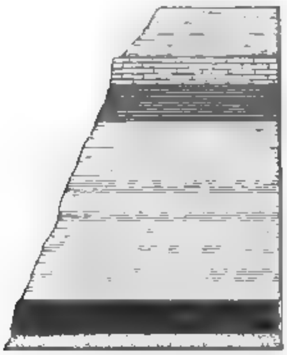
Coal.

While Madison county lies within the limits of the coal measures there are at present no mines of more than local importance. The Missourian formation, which covers so large a portion of the area is practically barren. The only coal beds of importance known to occur in this formation are found in beds that lie above the divisions of the Bethany limestone outcropping here. The black shale horizons noted in the general section of the formation carry some impure coal, but neither in quantity nor quality is it important.

The upper portion of Des Moines formation, as exposed along the Raccoon river, contains three horizons along which coal has been generally found. Two of these coal horizons have been named respectively the Lonsdale and the Marshall, and between these is an intermediate horizon to which no name has been given.

This intremediate coal appears on Bulger creek in Jefferson township, Madison county. Coal was formerly worked in Madison township (section 25) and it is not improbable that it belonged to the Lonsdale horizon. The coal found in Crawford township, on Cedar creek (sections 17 and 18), south of Patterson (section 32) and southwest of Bevington (section 36) can not be definitely correlated. Coal horizons have been noted in the sections near St. Charles, and similar beds occur at approximately the same levels along Clanton Creek and Middle river.

All these coal beds are quite thin. In many cases only a little impure coal is mixed with the black shale. The thickest beds noted include that reported at the old Clarke mine (Tp. 77 N., R. XXVIII W., Sec. 25, Nw. qr.) and that south of Patterson (Tp. 76 N., R. XXVI W., Sec. 32, Ne. qr., Sw. $\frac{1}{4}$). At the Clarke mine the bed is said to have been two feet thick. White gives the following section:

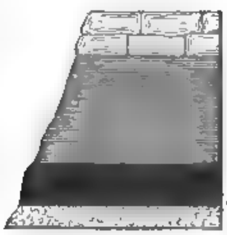


	FEET.
6. Shale, sandy	32
5. Limestone, impure, bluish	2
4. Shales, black, bituminous	3
3. Sha'e, argillaceous, bluish	14
2. Coal	2
1. Fire clay	1

FIG. 80. Coal at Clarke mine.

The coal would seem from this section to represent the Marshall horizon. It is not now exposed.

The section south of Patterson is as follows:

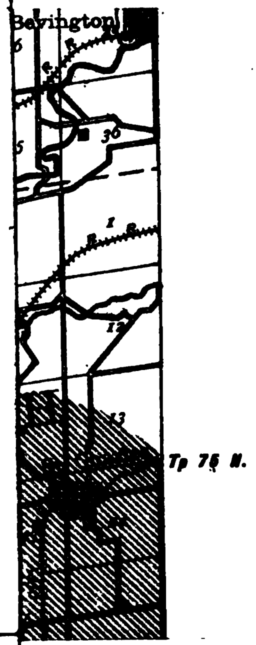


	FEET.	INCHES.
4. Limestone, gray, compact, fossiliferous	1	
3. Shale	2	6
2. Coal	2	
1. Fire clay		6

FIG. 81. Coal bed near Patterson.

The mines of Madison county are small, and are worked only in the winter to supply the local trade. Some coal is obtained by stripping and some by drifting. No deep shafts have been sunk, and no extensive prospecting has as yet been undertaken. Thick, workable beds probably occur within the county, but at some depth beneath the surface. At Van

Meter, just outside Madison county, two veins have been worked. One lies 285 feet below the surface, which is 884 A. T., and the other about twenty feet below. Each vein averages about three feet in thickness. In Guthrie thick coal has been found at several points at equivalent levels below the Bethany limestone. In Polk, Marion and Monroe counties coal is taken from horizons which are below the beds of Madison county. How far west along these horizons the coal will prove thick enough for mining is an open question, and can only be solved by drilling. At Peru, in 1887, the Chicago Great Western railway put down a hole to a depth of 303 feet. At 212 feet a thin bed of coal is said to have been encountered. This is about the horizon at which the coal worked at Commerce should occur if present. There are thin coal beds worked in Warren county, the uppermost passing beneath the bed of Middle river close to the east county line. This horizon usually shows sixteen inches of coal. Forty-five feet below is a horizon showing coal of equal thickness, and thirty-five feet still deeper is a horizon with eighteen inches. Probably coal may be found along these horizons over a portion of the county. The beds have a general dip toward the southwest of three to four feet per mile, and seem to have been but little disturbed.



BY

J. L. TILTON

1897.

LEGEND

GEOLOGICAL FORMATIONS

INDEX.